CONESTOGA-ROVERS
& ASSOCIATES

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April 10, 2015 Reference No. 018224-05

Ms. Carolyn Bury
U.S. EPA Region 5
LU-9J
77 West Jackson Blvd
Chicago, IL 60604-3507

960676

Dear Ms. Bury,

Re: 2015 Biannual Monitoring Plan
Halowax Area (Area 17) Interim Remedial Measure
East Plant
Wyandotte, Michigan

1.0 Introduction

On behalf of Legacy Site Services, LLC (LSS), Agent for Arkema Inc., Conestoga-Rovers & Associates, Inc. (CRA) has prepared this Biannual Monitoring Plan (Plan) in response to the United States Environmental Protection Agency (U.S. EPA) letter dated March 20, 2015.

The U.S. EPA requested an updated Plan to reflect monitoring adjustments, which included reduction of monitoring frequency from quarterly to biannually, removal of IRM-MW-3 from the sampling network, and removal of chromium and lead from the analyte list. The updated Plan includes the following components:

- A summary of the Area 17 Interim Measure
- Wells within the monitoring network and a figure showing their location
- Information about the wells such as screened intervals
- Cross-sectional diagrams
- Groundwater analyte list including volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs)
- Corrective Action Objectives (CAOs) for the groundwater based on the Michigan Act 451, Part 201 criteria for nonresidential property and the groundwater/surface water interface (GSI) criteria, as available
- Observations of DNAPL
- Standard operating procedures (SOPs) for field collection and analytical methods
- Sampling and reporting schedules
- Description of the Biannual monitoring report content, that includes, at a minimum, a table reporting the groundwater concentrations compared to CAOs/GSI criteria and highlighting

any detected concentrations exceeding criteria; a narrative describing results exceeding criteria; and measurements of DNAPL (depth to water, depth to DNAPL, total depth, DNAPL thickness)

The following sections of this Plan provide information requested by the U.S. EPA and serve as the 2015 Biannual Monitoring Plan for Area 17.

2.0 Summary of the Area 17 Interim Measure

The Halowax Area (Area 17 Interim Measure) occupies the northeast corner of the East Plant property. The subsurface stratigraphy is characterized by an upper layer of fill material (3 to 10 feet in thickness), underlain generally by silty sand and ultimately by a continuous 30 to 40 foot thick clay layer. The depth to the clay along the west side of the Halowax Area is approximately 10 feet and slopes to the east to a depth of approximately 20 feet along the Trenton Channel. Based on past hydraulic monitoring conducted throughout the East Plant, shallow groundwater in Area 17 generally flows to the east, toward the Trenton Channel (i.e., toward the containment wall). DNAPL flow, if occurring, is controlled by the subsurface clay layer dipping to the east. Historical sampling conducted as part of RCRA Corrective Action (CA) activities indicated the presence of DNAPL and dissolved organic compounds (predominantly chloroform, chlorinated naphthalenes and benzenes located at the sand/clay interface), which facilitated installation of an interim remedial measure (IRM) within the Halowax Area starting in 2000. The IRM was designed to mitigate migration of Halowax Area DNAPL and constituents into the Trenton Channel. The IRM includes the following elements:

1. **Containment walls keyed a minimum of 3 feet into the native clay layer:** The north and east boundaries of the Halowax Area include a combination of steel sheetpile and slurry walls for hydraulic control. The sheetpile walls were installed in 2000 and the slurry wall was installed in 2006. The containment features are as follows:
   - 300 foot long sheetpile wall along the northern property boundary (all joints prepared with Adeka A-50 sealant to create an impermeable barrier)
   - 600 foot vibrated beam slurry wall tied into the western edge of the northern sheetpile wall and extended west
   - 384 feet long sheetpile containment wall along the Trenton Channel (all joints prepared with Adeka A-50 sealant to create an impermeable barrier)
   - 20 foot long “wing” wall at the south end of the Trenton Channel containment wall (all joints prepared with Adeka A-50 sealant to create an impermeable barrier)

2. **Groundwater extraction system:** The Halowax Area treatment system collects impacted groundwater and DNAPL from two extraction wells (RW-1 and RW-2) that are located within an interceptor trench running parallel to the Trenton Channel and just inside the sheetpile containment wall (Refer to figure 1.0 for locations of recovery wells). The system extracts groundwater at an average rate (calculated on a monthly basis) of approximately 300 gallons per day. The range is typically between 200 and 400 gallons per day but depending on the season and rainfall, the system has removed up to approximately 850 gallons per day.

3. **Groundwater treatment system:** Captured groundwater and DNAPL are pumped to a 10 foot by 12 foot treatment building where DNAPL is collected and removed and groundwater is treated prior to discharge to the local POTW. The first step in the system is a conical DNAPL collection tank. Water at the top of the tank gravity flows for further treatment, while DNAPL accumulates at the bottom for removal. DNAPL is collected through a valve at the bottom of the conical tank on a monthly basis, as part of standard operation and maintenance activities. Since regular operation of the system began in 2001, approximately 495 gallons of DNAPL has been recovered. Following DNAPL separation, water gravity flows into an iron filter and then an equalization tank (EQ tank). When the EQ tank reaches capacity, water is pumped through bag filters and then liquid-phase granular activated carbon (GAC) for final treatment prior to discharge to the POTW.

4. **Enhanced groundwater extraction (Phytoremediation):** 200 trees were planted within the Halowax Area to facilitate passive groundwater extraction. A total of 140 willows and 60 poplars were installed on a 25-foot grid spacing (spacing varied depending on presence of former building slabs and structures). The trees were planted throughout the area south of the north sheetpile wall and west of the east sheetpile wall, covering an area approximately 250 feet by 250 feet (1.5 acres).

5. **Soil cover:** 1.5 foot clay cover between the Site access road and sheetpile wall along the Trenton Channel to limit infiltration in the area of groundwater extraction.

6. **Groundwater monitoring network:** Groundwater and surface water elevations have been monitored since installation of the IRM in 2001. Select Area 17 wells shown on figure 1.0 and the surface water elevation in the Trenton Channel have been gauged (surface water levels only) regularly since 2001 using an electronic water level indicator to evaluate hydraulic gradients. When comparing surface water levels to groundwater levels in the monitoring wells located closest to shore (IRM-MW2, IRM-MW3, RW-1 and RW-2), an inward gradient is predominant, which demonstrates that the containment and recovery

system is depressing the water table near the containment wall and limiting migration of impacted groundwater toward the Trenton Channel.

MW025, located at the southern end of the sheet pile wall, was installed to evaluate the effectiveness of the containment system. MW025 was placed specifically to understand whether contaminated groundwater or DNAPL was migrating around the southern end of the wall and discharging to the Trenton Channel. During installation of MW025, no DNAPL was identified visually or through screening using Sudan IV (a substance used to indicate the presence of DNAPL in sediment samples). Additionally, subsequent sampling events have shown that DNAPL is not present and that groundwater within MW025 contains only trace concentrations of VOCs and SVOCs.

With respect to NAPL, Halowax area wells have been periodically evaluated for the presence of DNAPL. Wells within Area 17 are typically screened at the top of the clay layer (e.g., MW009) and certain wells (IRM-MW-1, IRM-MW-2, IRM-MW-3 and MW025) are constructed with "sumps" beneath the well screens, which are keyed into the lower clay layer. Any DNAPL , if present and mobile, should flow along the top of the clay layer (dipping to the east – toward the containment wall) and be observed within the screened section or fall into the sumps and accumulate (exaggerating DNAPL thickness). Since initiating RCRA CA activities, DNAPL has been documented in MW009 and IRM-MW-2 only, which indicates DNAPL plume stability. The DNAPL is black in color and viscous and consistent with what is observed in the Halowax Area treatment system waste stream.

In summary, the treatment system consists of containment, recovery and treatment elements that are collectively:

- Capturing and removing DNAPL from the subsurface (approximately 495 gallons to date)
- Containing, capturing and treating impacted groundwater within Area 17 (approximately 1,278,300 gallons to date)
- Preventing migration of impacted groundwater and DNAPL to the north, east and around the southern portion of the containment wall to the south

3.0 Area 17 Groundwater Corrective Action Objectives

As identified in the May 2010 CMS report for the East Plant, the recommended corrective action for groundwater impacts in Area 17 includes the use of institutional controls to restrict use of Area 17, thereby mitigating potential exposure pathways associated with constituents in groundwater (restricting construction of buildings and intrusive activities) and a regular monitoring program to ensure the treatment system elements are performing as designed.

The objectives of the Biannual sampling events detailed herein are to supplement the conclusions presented in the May 2010 CMS Report which maintain that the current system effectively contains, captures, recovers and treats (or disposes) impacted groundwater and DNAPL prior to migration to the Trenton Channel.

To achieve this objective, networks of monitoring wells (detailed in the subsequent sections) will be sampled and/or gauged on a Biannual basis to evaluate groundwater flow direction, evaluate DNAPL presence/thickness and evaluate dissolved constituent concentrations. Groundwater flow assessments will be used to show that hydraulic conditions are such that impacted groundwater within Area 17 is being intercepted by the barrier walls (i.e., if groundwater flow maintains an easterly direction, the impermeable barrier walls are properly placed to contain impacts). DNAPL assessments will be used to show that the DNAPL plume is not expanding and, over time, help to show that DNAPL volumes in the subsurface are decreasing. Given the impermeable nature of the slurry and sheet pile wall systems along the north and east sides of Area 17, which function to prevent migration of impacted groundwater and DNAPL to the north and east, MW025 is considered the most important point for monitoring compliance. Based on barrier design, impacted groundwater/DNAPL would be most susceptible to migration around the wall at this southernmost point.

All groundwater samples collected as part of the Biannual sampling events will be analyzed for Target Compound List (TCL) volatile organic compounds (VOCs) and TCL semi-volatile organic compounds (SVOCs), in accordance with U.S. EPA publication SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*. Analytical results will be compared to applicable Michigan Act 451, Part 201 Generic Cleanup Criteria. Since the Site is under a restrictive covenant which limits the Site to nonresidential (Industrial) uses and prohibits use of groundwater for drinking water purposes, applicable criteria will be limited to Nonresidential Groundwater Volatilization to Indoor Air Inhalation Criteria (all well locations) and Groundwater Surface Water Interface (GSI) criteria (MW025 only).

4.0 Area 17 Monitoring Well Details and Historical DNAPL Observations

Monitoring wells located in and near Area 17 are shown on figure 1.0. The table below shows well details, along with historical DNAPL observations within the wells. Refer to Attachment A for stratigraphic and instrumentation logs. Refer to Attachment B for cross-sectional diagrams.

Well ID	Interval	TOC Elev.[1]	Water Level (ft btoc)[2]	Depth to DNAPL (ft btoc)	TOS[3]	BOS[4]	Screened Interval
IRM-MW-1	Shallow	580.02	6.10	ND	12.25	17.25	silty sand, 5' sump keyed into clay [5]
IRM-MW-2	Shallow	579.57	6.10	16.90	11.52	16.52	fill, 5' sump keyed into clay [5]
IRM-MW-3	Shallow	579.30	5.80	ND	11.31	16.31	fill, 5' sump keyed into clay [5]
MW009	Shallow	579.57	5.42	8.30	11.14	16.14	silty sand
MW010a	Shallow	579.76	4.78	ND	6.52	11.52	poorly graded sand
MW011	Shallow	580.66	4.89	ND	5.17	10.17	fill/sand
MW016	Shallow	579.29	5.52	ND	17.25	22.25	silt/sand/clay
MW017	Shallow	Well damaged					
MW022	Shallow	Well damaged					
MW025	Shallow	581.11	7.62	ND	16.91	21.91	fill, sump keyed into clay
MW109	Intermediate	578.56	8.75	ND	29.12	39.12	clayey silt (confined)
MW209	Deep	579.73	14.69	ND	51.50	61.50	limestone (confined)

Notes:
[1] NAVD 88
[2] ft btoc - feet below top of casing (water levels shown for shallow monitoring wells are from 10/9/2014. Water levels for intermediate and deep wells are from gauging on 1/30/14)
[3] TOS – approximate top of screen (feet below top of casing)
[4] BOS - approximate bottom of screen (feet below top of casing)
[5] Well installation not observed by CRA – see well details provided by Parson's Engineering Science, Inc. in Attachment A
"ND" – No Historical DNAPL Detections in this monitoring well

Biannual events in 2015 will include gauging and DNAPL assessments in eight monitoring wells (IRM-MW-1, IRM-MW-2, IRM-MW-3, MW009, MW010A, MW011, MW016 and MW025) and sampling of five monitoring wells (IRM-MW-1, IRM-MW-2, MW010A, MW016 and MW025). Damaged wells and wells located in the intermediate and deep zones (MW109 and MW209) will not be sampled or gauged. The detailed groundwater monitoring plan is provided in Section 5.0.

5.0 Halowax Area (Area 17 Interim Measure) Groundwater Monitoring Plan

This task accounts for Biannual hydraulic/DNAPL monitoring and sampling of shallow monitoring wells within the Halowax Area in 2015. Following the November, 2015 sampling event, the number of wells and frequency of sampling will be re-evaluated and, if warranted, modifications to the network and sampling frequency will be proposed in the second Biannual report. A tabulated summary of the 2015 Biannual Monitoring Plan follows and the remaining sections detail field procedures/ protocols, laboratory analyses and reporting to meet U.S. EPA requirements.

Sampling Event	Hydraulic Monitoring/DNAPL Gauging Network	Sampling Network	Analyses	Report Delivery to U.S. EPA
April 2015	IRM-MW-1 IRM-MW-2 IRM-MW-3 MW009 MW010A MW011 MW016 MW025	IRM-MW-1 IRM-MW-2 MW010A MW016 MW025 (GSI monitoring point)	TCL VOCs TCL SVOCs QA/QC – 1 Trip, 1 Dup, 1 MS/MSD	June 2015
November 2015	IRM-MW-1 IRM-MW-2 IRM-MW-3 MW009 MW010A MW011 MW016 MW025	IRM-MW-1 IRM-MW-2 MW010A MW016 MW025 (GSI monitoring point)	TCL VOCs TCL SVOCs QA/QC – 1 Trip, 1 Dup, 1 MS/MSD	January 2016

5.1 Health and Safety Plan

Prior to beginning biannual sampling, CRA will update the Health and Safety Plan (HASP) for Site work. The HASP will describe health and safety procedures and emergency response guidelines to be implemented during the work. Field sampling personnel will maintain 40-hour Hazardous Waste Operations and Emergency Response (HAZWOPER) safety training and annual 8-hour refresher courses required by CFR Parts 1910 and 1926.

5.2 Fluid Level Monitoring

To start each event, static water levels (using an Oil/Water Interface Probe) will be collected from all existing shallow monitoring wells in and near Area 17 to define hydraulic conditions and investigate the presence of DNAPL. As summarized above, these wells include IRM-MW-1, IRM-MW-2, IRM-MW-3, MW009, MW010A, MW011, MW-016, and MW025. Monitoring wells MW017 and MW022, shown on figure 1.0, are damaged and will not be sampled as part of these events.

Monitoring well caps will be removed for a sufficient amount of time prior to water level measurement to ensure pressure differences in the well casings do not impact water levels. Surface water levels of the Trenton Channel will also be obtained during the event. The river level will be calculated from data provided by the National Oceanic and Atmospheric Administration (NOAA) Wyandotte River Gauging Station website (http://glakesonline.nos.noaa.gov/glin.shtml?station_info=9044030+Wyandotte+MI).

CRAs Field Method Guideline (FMG) for Fluid Level Monitoring Standard Operating Procedures will be followed, as applicable, during these activities. Refer to Attachment C for field SOPs.

5.3 Groundwater Sampling

Each monitoring well will be sampled in accordance with low-flow procedures using a peristaltic pump. Tubing used for sampling will be dedicated to each monitoring well to prevent potential cross-contamination, eliminate decontamination of tubing and to facilitate follow-up sampling rounds. During sampling, the water level and pumping rate will be recorded every three to five minutes (or less, depending on the recharge rate of the monitoring well) and the groundwater will be monitored with a flow-through cell for field parameters including dissolved oxygen (DO), oxidation reduction potential (ORP), pH, specific conductance, turbidity, and temperature. After the field parameters have stabilized, groundwater samples will be collected using laboratory-supplied glass containers, starting with VOCs. Field quality control samples will also be collected during the sampling event and will consist of one trip blank, one duplicate and one matrix spike/matrix spike duplicate (MS/MSD). Upon collection, samples will immediately be placed in a cooler on ice for shipment to the analytical laboratory.

CRA's FMG for Groundwater Sample Purging and Collection Procedures will be followed, as applicable, during field activities. Refer to Attachment C for field SOPs. Attachment C also presents an example record form for low-flow purging.

All water generated during sampling will be processed through the Halowax Area groundwater treatment system.

5.4 Field Documentation

Documentation of sampling information and other observations made by CRA during the sampling activities will include details, such as: the date and location of sample collection, personnel and hours on-Site, the type of sample collected, the method in which the sample was collected, the types of sampling containers and preservatives used, problems encountered during sampling, and type of analytical testing. Sampling activities will be documented using:

- Daily Field log-books
- Low-Flow Purging Forms (see Attachment C)
- Chain-of-Custody (COC)Forms

5.5 Laboratory Analyses

Groundwater samples collected for chemical analysis will be submitted to TestAmerica Laboratories for standard turnaround time (approximately two weeks) under COC protocol and samples will be analyzed for TCL VOCs by SW846, Method 8260 and TCL SVOCs by SW846, Method 8270.

Quality Assurance/Quality Control (QA/QC) procedures will be conducted by the laboratory during sample analyses. A QA/QC review of laboratory analytical data and data validation will be performed by a CRA chemist.

5.6 Biannual Reporting

Upon completion of sampling and laboratory analyses, CRA will prepare a report of findings. The report will include the following components in accordance with the requirements of the U.S. EPA:

- narrative describing field procedures, analytical methods and results
- figure showing the monitoring network and groundwater contours
- figure showing cross-sectional diagram of the hydrogeologic profile
- table reporting the groundwater concentrations compared to applicable Part 201 Nonresidential Criteria and highlighting any detected concentrations exceeding criteria
- A table reporting well details, water levels and observations of DNAPL (depth to water, depth to DNAPL, total depth, DNAPL thickness)
- Data validation memorandum

The Biannual reports will be submitted to the U.S. EPA on a Biannual basis within 4 weeks of receipt of final analytical data. Taking into account laboratory turn-around-time, reports are anticipated to be delivered to the U.S. EPA in the months of June 2015 and January 2016.

We trust that this Plan satisfies your requirements at this time. If you should have any questions or comments or require further clarification, please contact Mr. Michael Pinto at (610) 594-4435.

Sincerely,

CONESTOGA-ROVERS & ASSOCIATES

Peter S. Swanson, P.E.

PSS/drc/6/Det.

Encls: Figure 1 - Site Layout
Attachment A - Stratigraphic and Instrumentation logs
Attachment B - Cross-Sectional Diagrams
Attachment C - Standard Operating Procedures

c.c.: Michael Pinto, LSS
Michael Bollinger, Beazer East
Joanne West, Union Carbide
Peter Quackenbush, MDEQ
Laura Verona, MDEQ
Dave Canfield, CRA

Figure

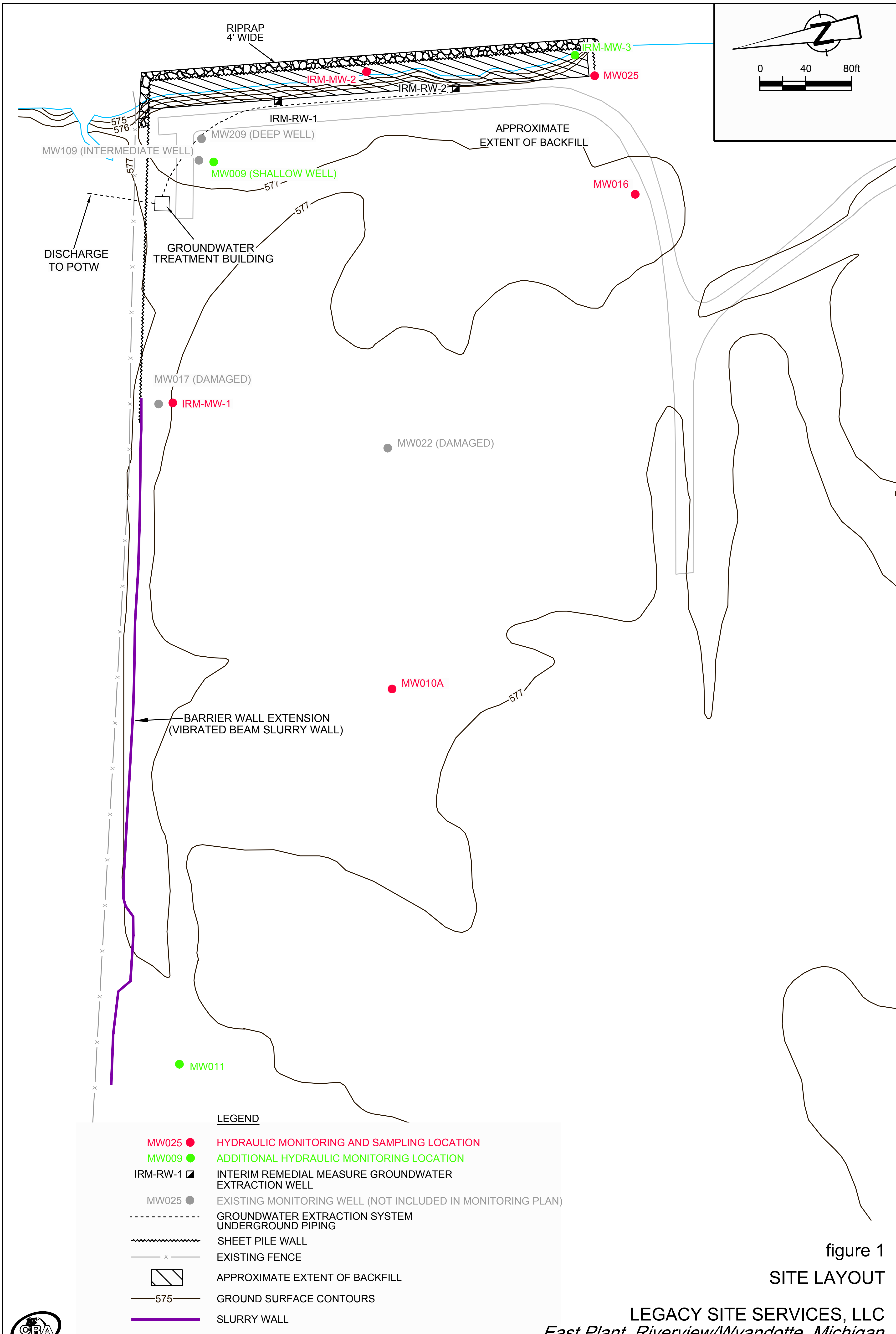


figure 1

SITE LAYOUT

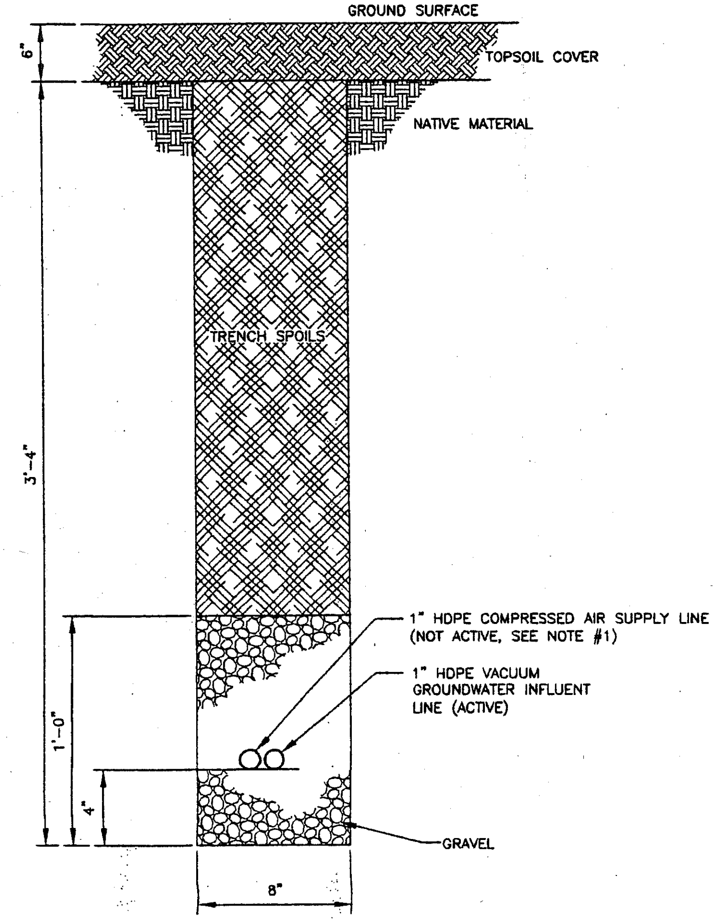
LEGACY SITE SERVICES, LLC

East Plant, Riverview/Wyandotte, Michigan

018224-05(BURY006)GN-DE001 MAR 26/2015

Attachment A

Stratigraphic and Instrumentation Logs

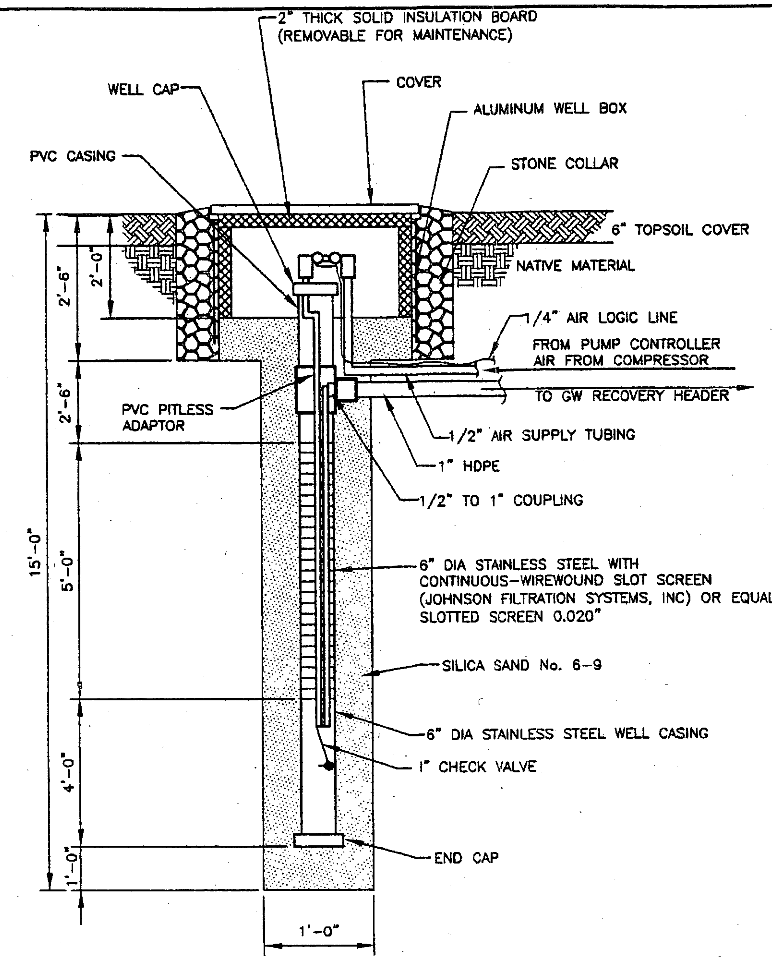


NOTES:

1. DESIGN CHANGE FROM PNEUMATIC BLADDER PUMPS TO VACUUM PUMPS RENDERED THE 1" HDPE COMPRESSED AIR SUPPLY LINE AS INACTIVE.

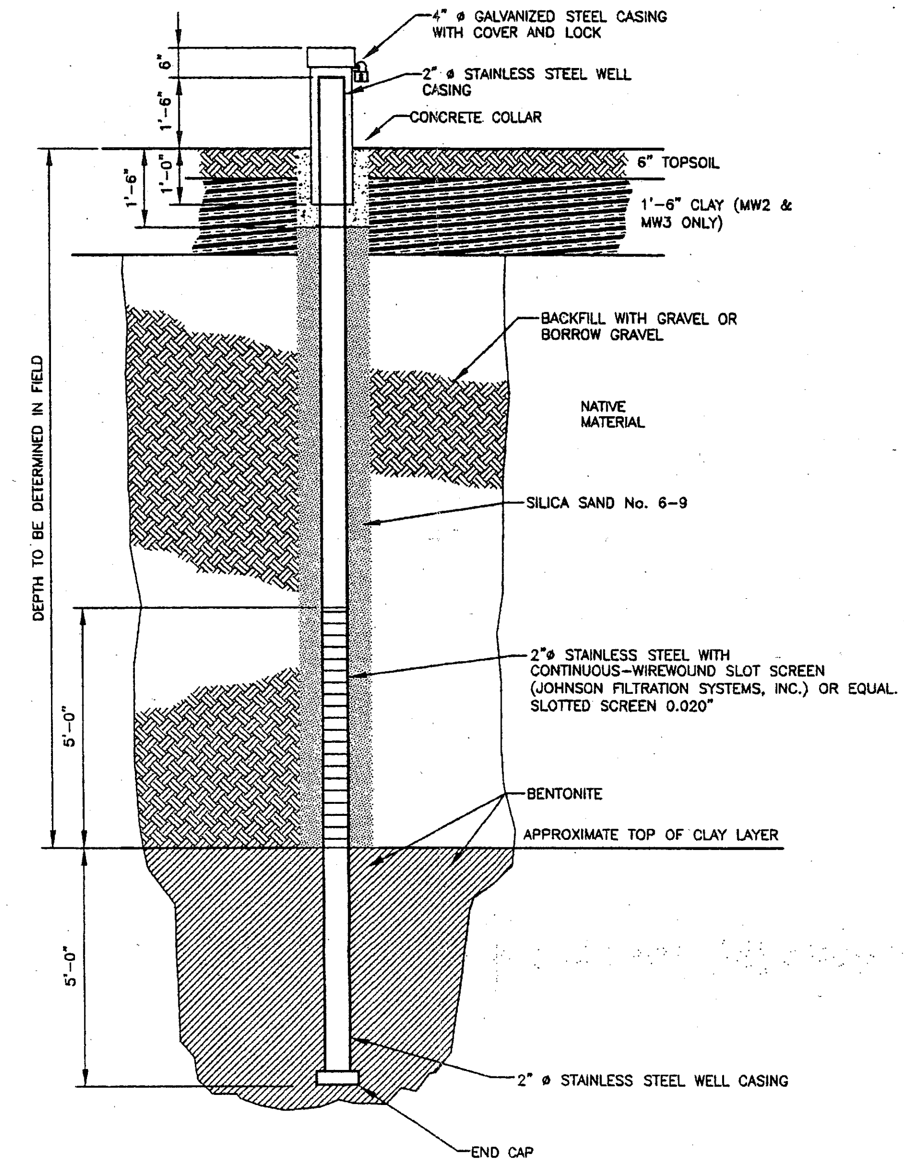
2. THE MAXIMUM GROUNDWATER TABLE LEVEL IS EXPECTED TO BE 48" BELOW FINAL GRADE. THE FROST LINE IS EXPECTED TO BE 40" BELOW GROUND SURFACE.

3 / C-1 TRENCH DETAIL
NOT TO SCALE



WELL SCHEDULE		
WELL	BORING DEPTH	SCREEN INTERVAL
RW-1	15 FT.	5-10 FT.
RW-2	15 FT.	5-10 FT.

1 / C-1 TYPICAL EXTRACTION RECOVERY WELL DETAIL
NOT TO SCALE



WELL SCHEDULE		
WELL	BORING DEPTH	SCREEN INTERVAL
MW-1	20 FT.	10-15 FT.
MW-2	20 FT.	10-15 FT.
MW-3	20 FT.	10-15 FT.

NOTE:

TOP OF CLAY LAYER MAY VARY. BOTTOM OF SCREEN INTERVAL TO BE LOCATED AT OR SLIGHTLY BELOW CLAY LAYER.

2 / C-1 TYPICAL MONITORING WELL DETAIL
NOT TO SCALE

RECORD DRAWING

THESE DRAWINGS HAVE BEEN REVISED TO REFLECT MAJOR CHANGES, IF ANY, WHICH OCCURRED DURING CONSTRUCTION. REVISIONS ARE BASED UPON INFORMATION FURNISHED BY CONTRACTOR.

PER: ________ DATE: ________

Rev	Date	Description	By
2		FINAL RECORD DRAWING ISSUE	
1	6/21/00	RECORD DRAWING	JPM
0	1/5/99	ISSUED FOR CONSTRUCTION	JPM

Job No. 734232
Designed MDM
Drawn JHG
Checked DAB
Reviewed JPM
Approved JPM
Reg. No.
Date

Issue Certification

PARSONS ENGINEERING SCIENCE, INC.
LIVERPOOL, N.Y.
(315) 451-9560

HALOWAX AREA SITE
WYANDOTTE, MICHIGAN

WELL AND TRENCH DETAILS

DRAWING NO. C-3
REV. 2

No XREFs
P:\734232\cad\FIN-RECD-2-01\34232C03.dwg, 02/05/01 at 12:09, MJC, 1=1

BOREHOLE ID : MW9 *SITE NAME/NO:* ELF ATOCHEM
BEGIN DATE : 04/24/86 *END DATE :* 04/24/86

LOGGER/COMPANY : B.W.B.

BOREHOLE COMPLETED IN (<O>verburden <B>edrock) : O

TOTAL DEPTH : 18.00 *DEPTH TO BEDROCK :* 0.00

BOREHOLE DIAMETER #1: 8.00
INTERVAL: 0.00 ft. to 16.00 ft. BGS
METHOD : HSA *FLUID :* NONE
BOREHOLE DIAMETER #2: 2.00
INTERVAL: 16.00 ft. to 18.00 ft. BGS
METHOD : SPLIT SPOON *FLUID :* NONE
BOREHOLE DIAMETER #3:
INTERVAL:
METHOD : *FLUID :*

DRILLING COMPANY : MCDOWELL
DRILLER :
DRILL RIG TYPE : CME 55

	ESTIMATED	*SURVEYED*
SURFACE ELEVATION :	577.230	
N. COORDINATE :	0.0000	9354.1815
E. COORDINATE :	0.0000	10928.2292

WELL PERMIT......(Y)es (N)o: N *PERMIT # :*

HOLE ABANDONED...(Y)es (N)o: N
WELL INSTALLED...(Y)es (N)o: Y
WELL CLUSTER.....(Y)es (N)o: N *No. OF WELLS :* 0
WELL NEST........(Y)es (N)o: N *No. OF WELLS :* 0
PUMPS INSTALLED..(Y)es (N)o: N

	TYPE	*DEPTH*
PURGE :		0.00
SAMPLE :		0.00

BOREHOLE TESTING
BOREHOLE GEOPHYSICS.....(Y)es (N)o: N
SLUG TESTS..............(Y)es (N)o: N
PACKER TESTS............(Y)es (N)o: N
PUMPING TESTS...........(Y)es (N)o: N

COMMENTS :
Shallow well.

Well Completion Summary

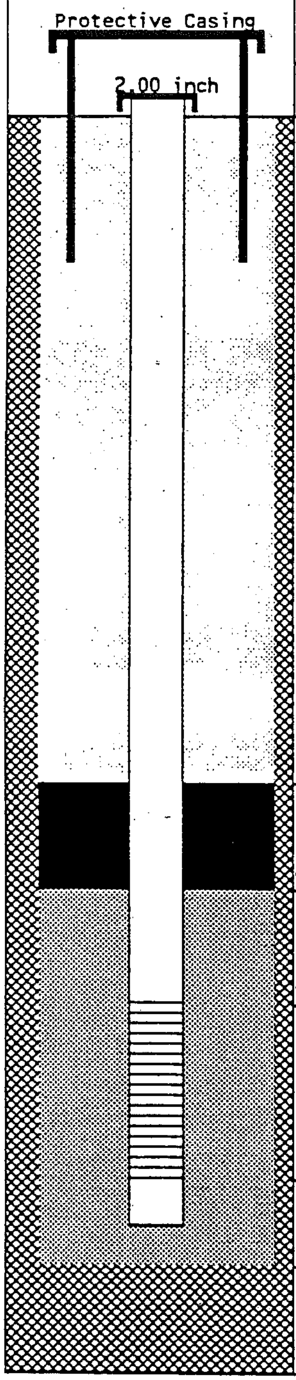
Roy F. WESTON, Inc.

CLIENT ELF ATOCHEM
SITE NAME

DRILLING FIRM
INSPECTOR B.W.B.

WELL ID MW9
START DATE 04/24/86
COMPLETION DATE 04/24/86

WATER LEVELS



DEPTH		ELEV.
2.48	TC	579.71
0.00	GS	577.23
4.40	BN	572.83
6.00	SP	571.23
9.00	SC	568.23
14.00	BS	563.23
14.00	TD	563.23

DRILLING SUMMARY

Driller
Drilling Fluid
Well Type SINGLE CASED SCREENED

WELL DESIGN CONSTRUCTION

Casing #1 Diameter: 2.00 **inch** **Interval:** 0.00 to 9.00 **ft.**
Type :

Stick Up Inner Casing: 2.48 **ft.** **Protective Casing:** 0.00 **ft.**

Casing Grout: OTHER **Interval:** 0.00 to 4.40 **ft.**

Seal Type: BENTONITE PELLETS **Interval:** 4.40 to 6.00 **ft.**

Sand Pack Type : MEDIUM-COARSE **Interval:** 6.00 to 14.00 **ft.**
Grain Size : MIXED **Median Diameter:**
Screen Diameter: 2.00 **Interval:** 9.00 to 14.00 **ft.**
Type : PVC **Slots:** **inches**

Silt Trap Interval: 0.00 to 0.00 **ft.**
Backfill Type : SAND **Interval:** 14.00 to 16.00 **ft.**

WELL DEVELOPMENT

Date / /
Method Bail
Yield **Purged Volume**

COMMENTS

TC = Top of Casing
GS = Ground Surface
BN = Top Seal
SP = Top Sand Pack
SC = Top Screen
BS = Bottom Screen
TD = Total Depth
= Grout
= Seal
= Sand Pack
= Formation

Additional Comments:

NOTE: Well Diagram not to Scale

Elevations are feet above mean sea level

Borehole Log

Roy F. WESTON, Inc.

CLIENT : ELF ATOCHEM		TOTAL DEPTH	: 18.00
SITE NAME :		LOGGER	: B.W.B.
WELL ID : MW9		DRILLING COMPANY	: MCDOWELL
NORTHING : 9354.1815 surveyed		DRILLING RIG	: CME 55
EASTING : 10928.2292 surveyed		DATE STARTED	: 04/24/86
ELEVATION : 577.230 estimated		DATE COMPLETED	: 04/24/86

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
	0			Fill	DK GRAY		DRY	3 4 3 5	HNU 0.5	Dark gray gravelly silty sand fill; stained; trace coal.
576	1									
575	2			Fill	DK GRAY		DMP	3 3 4 5	HNU 0.5	Dark gray gravelly silty sandy fill; damp; stained trace coal.
574	3									
573	4			Fill	DK GRAY-BLACK		WET	8 5 3 4	HNU 4.0	Dark gray to black silty sandy fill; wet; oily stained, w/white fiberous material; sheet metal pcs
572	5									
571	6			Fill	DK GRAY-BLACK		SAT	3 2 2 3	HNU 4.0	Dark gray to black sandy, fill; saturated; very oily.
570	7									
569	8			Silty sand	OLIVE BROWN		WET		HNU 4.0	
				Silty sand	OLIVE BROWN		WET	6 8 8 8	HNU 1.0	Olive brown silty fine sand; wet with streaks of black oil stains.
568	9									
567	10			Silty sand	OLIVE BROWN		WET	4 4 3 4	HNU 4.0	Same above with occasional black oil streaks.

Borehole Log

Roy F. WESTON, Inc.

CLIENT	: ELF ATOCHEM		TOTAL DEPTH	:	18.00
SITE NAME	:		LOGGER	:	B.W.B.
WELL ID	: MW9		DRILLING COMPANY	:	MCDOWELL
NORTHING	: 9354.1815 surveyed		DRILLING RIG	:	CME 55
EASTING	: 10928.2292 surveyed		DATE STARTED	:	04/24/86
ELEVATION	: 577.230 estimated		DATE COMPLETED	:	04/24/86

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Silty sand	OLIVE BROWN		WET		HNU 4.0	Same above with occasional black oil streaks.
566	11									
565	12			Silty sand	OLIVE BROWN		WET	7 9 10 11	HNU 6.0	Same as above with occasional black oil streaks.
564	13									
563	14			Sandy clay, lt gravel	GRAY BROWN		DMP	7 13 10 17	HNU 3.0	Fine sandy clay; damp; low to med. plastic with little subangular fine gravels, low recovery- 3"
				No Sample Recovered						
562	15									
561	16			Sandy clay	GRAY BROWN		DMP	5 13 11 15	HNU 8.0	As above but with slightly more sand content.
560	17									
559	18									
558	19									
557	20									

BOREHOLE /WELL ID	SMP NUM	LTH NUM	LITHOLOGY INT. (FT BGS)		SAMPLING METHOD	SIZE GRAVEL	GRAVEL PCT.	SIZE SAND	SAND PCT	SILT PCT	CLAY PCT	ORGANIC PCT	ROCK TYPE	PLAST	SORT	STRENGTH	MOISTURE	STRAT UNIT
MW9	1	1	0.00	2.00	SPS		0		0	0	0	0					DRY	
MW9	2	1	2.00	4.00	SPS		0		0	0	0	0					DMP	
MW9	3	1	4.00	6.00	SPS		0		0	0	0	0					WET	
MW9	4	1	6.00	7.90	SPS		0		0	0	0	0					SAT	
MW9	4	2	7.90	8.00	SPS		0	F	0	0	0	0					WET	
MW9	5	1	8.00	10.00	SPS		0	F	0	0	0	0					WET	
MW9	6	1	10.00	12.00	SPS		0	F	0	0	0	0					WET	
MW9	7	1	12.00	14.00	SPS		0	F	0	0	0	0					WET	
MW9	8	1	14.00	14.26	SPS	F	0		0	0	0	0		MOD			DMP	
MW9	8	2	14.26	16.00	SPS		0		0	0	0	0						
MW9	9	1	16.00	18.00	SPS		0		0	0	0	0		MOD			DMP	

BOREHOLE ID : MW10A SITE NAME/NO: ELF ATOCHEM
BEGIN DATE : 07/27/93 END DATE : 07/27/93

LOGGER/COMPANY : B. JAKUB

BOREHOLE COMPLETED IN (<O>verburden <B>edrock) : O

TOTAL DEPTH : 10.00 DEPTH TO BEDROCK : 0.00

BOREHOLE DIAMETER #1: 8.00
INTERVAL: 0.00 ft. to 8.00 ft. BGS
METHOD : HSA FLUID : NONE
BOREHOLE DIAMETER #2: 2.00
INTERVAL: 8.00 ft. to 10.00 ft. BGS
METHOD : SPLIT SPOON FLUID : NONE
BOREHOLE DIAMETER #3:
INTERVAL:
METHOD : FLUID :

DRILLING COMPANY : BOWSER-MORNER
DRILLER : G. VORE
DRILL RIG TYPE : MOBILE B-61

	ESTIMATED	SURVEYED
SURFACE ELEVATION :	577.600	
N. COORDINATE :	0.0000	9416.1655
E. COORDINATE :	0.0000	10445.9557

WELL PERMIT......(Y)es (N)o: N PERMIT # :

HOLE ABANDONED...(Y)es (N)o: N
WELL INSTALLED...(Y)es (N)o: Y
WELL CLUSTER.....(Y)es (N)o: N No. OF WELLS : 0
WELL NEST........(Y)es (N)o: N No. OF WELLS : 0
PUMPS INSTALLED..(Y)es (N)o: N

	TYPE	DEPTH
PURGE :		0.00
SAMPLE :		0.00

BOREHOLE TESTING
BOREHOLE GEOPHYSICS.....(Y)es (N)o: N
SLUG TESTS..............(Y)es (N)o: N
PACKER TESTS............(Y)es (N)o: N
PUMPING TESTS...........(Y)es (N)o: N

COMMENTS :
Shallow well - reinstalled.

Well Completion Summary

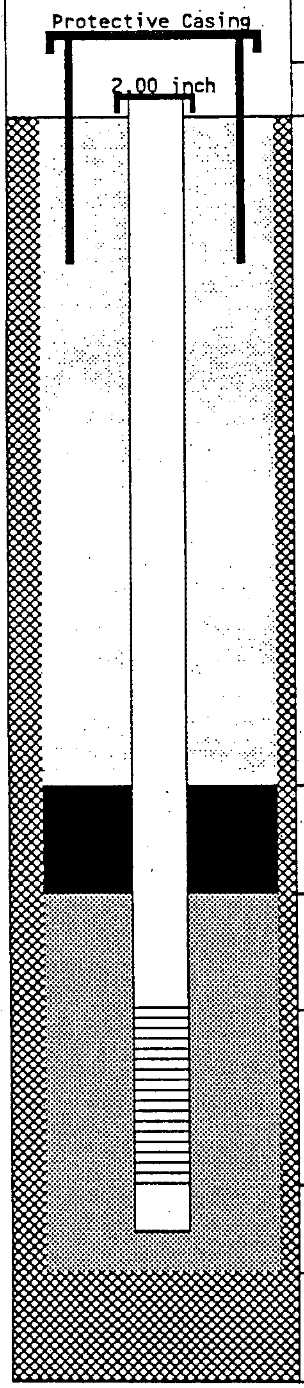
Roy F. WESTON, Inc.

CLIENT ELF ATOCHEM
SITE NAME

DRILLING FIRM BOWSER-MORNER
INSPECTOR B. JAKUB

WELL ID MW10A
START DATE 07/27/93
COMPLETION DATE 07/27/93

WATER LEVELS
5.60 FT (TOC) ON 07/28/93



DEPTH		ELEV.
2.16	TC	579.76
0.00	GS	577.60
2.30	BN	575.30
4.20	SP	573.40
4.50	SC	573.10
9.50	BS	568.10
9.50	TD	568.10

DRILLING SUMMARY

Driller G. VORE
Drilling Fluid NONE
Well Type SINGLE CASED SCREENED

WELL DESIGN CONSTRUCTION

Casing #1 Diameter: 2.00 *inch* *Interval:* 0.00 to 4.50 *ft.*
Type : PVC SCH 40

Stick Up Inner Casing: 2.16 *ft.* *Protective Casing:* 2.38 *ft.*

Casing Grout: CEMT/BENT *Interval:* 0.00 to 2.30 *ft.*

Seal Type: BENTONITE PELLETS *Interval:* 2.30 to 4.20 *ft.*

Sand Pack Type : BEST SAND #5 *Interval:* 4.20 to 9.50 *ft.*
Grain Size : *Median Diameter:* 1.5 mm
Screen Diameter: 2.00 *Interval:* 4.50 to 9.50 *ft.*
Type : PVC *Slots:* 0.010 *inches*

Silt Trap Interval: 0.00 to 0.00 *ft.*
Backfill Type : BEST SAND #5 *Interval:* 9.50 to 10.00 *ft.*

WELL DEVELOPMENT

Date 07/28/93
Method Bail and Surge
Yield *Purged Volume* 20 gal

COMMENTS

TC = Top of Casing
GS = Ground Surface
BN = Top Seal
SP = Top Sand Pack
SC = Top Screen
BS = Bottom Screen
TD = Total Depth
= Grout
= Seal
= Sand Pack
= Formation

Additional Comments:
Water levels recorded from top of inner casing.

NOTE: Well Diagram not to Scale

Elevations are feet above mean sea level

Borehole Log

Roy F. WESTON, Inc.

CLIENT	: ELF ATOCHEM	TOTAL DEPTH	: 10.00
SITE NAME	:	LOGGER	: B. JAKUB
WELL ID	: MW10A	DRILLING COMPANY	: BOWSER-MORNER
NORTHING	: 9416.1655 surveyed	DRILLING RIG	: MOBILE B-61
EASTING	: 10445.9557 surveyed	DATE STARTED	: 07/27/93
ELEVATION	: 577.600 estimated	DATE COMPLETED	: 07/27/93

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
	0			Interval Not Sampled						Augered interval.
576	1									
575	2									
574	3									
573	4									
572	5									
571	6									
570	7									
569	8		85	Poorly graded sand, SP	OLIVE BROWN	LSE	SAT			
				Silt, ML	DK GRAY	FRM	DRY			
568	9									
				No Sample Recovered						
567	10									

BOREHOLE /WELL ID	SMP NUM	LTH NUM	LITHOLOGY INT. (FT BGS)		SAMPLING METHOD	SIZE GRAVEL	GRAVEL PCT.	SIZE SAND	SAND PCT	SILT PCT	CLAY PCT	ORGANIC PCT	ROCK TYPE	PLAST	SORT	STRENGTH	MOISTURE	STRAT UNIT
MW10A	1	1	0.00	8.00	NS		0		0	0	0	0						
MW10A	2	1	8.00	8.70	SSS		0	F	95	5	0	0		NA	WEL	LSE	SAT	
MW10A	2	2	8.70	9.70	SSS	MF	3	M	2	85	10	0		LOW	MOD	FRM	DRY	
MW10A	2	3	9.70	10.00	SSS		0		0	0	0	0						

BOREHOLE ID : MW11 SITE NAME/NO: ELF ATOCHEM
BEGIN DATE : 04/22/86 END DATE : 04/22/86

LOGGER/COMPANY : B.W.B.

BOREHOLE COMPLETED IN (<O>verburden <B>edrock) : O

TOTAL DEPTH : 8.00 DEPTH TO BEDROCK : 0.00

BOREHOLE DIAMETER #1: 8.00
INTERVAL: 0.00 ft. to 8.00 ft. BGS
METHOD : HSA FLUID : NONE
BOREHOLE DIAMETER #2:
INTERVAL:
METHOD : FLUID :
BOREHOLE DIAMETER #3:
INTERVAL:
METHOD : FLUID :

DRILLING COMPANY : MCDOWELL
DRILLER :
DRILL RIG TYPE : CME 55

	ESTIMATED	SURVEYED
SURFACE ELEVATION :	578.460	
N. COORDINATE :	0.0000	9726.9457
E. COORDINATE :	0.0000	10232.4009

WELL PERMIT......(Y)es (N)o: N PERMIT # :

HOLE ABANDONED...(Y)es (N)o: N
WELL INSTALLED...(Y)es (N)o: Y
WELL CLUSTER.....(Y)es (N)o: N No. OF WELLS : 0
WELL NEST........(Y)es (N)o: N No. OF WELLS : 0
PUMPS INSTALLED..(Y)es (N)o: N

	TYPE	DEPTH
PURGE :		0.00
SAMPLE :		0.00

BOREHOLE TESTING
BOREHOLE GEOPHYSICS.....(Y)es (N)o: N
SLUG TESTS..............(Y)es (N)o: N
PACKER TESTS............(Y)es (N)o: N
PUMPING TESTS...........(Y)es (N)o: N

COMMENTS :
Shallow well.

Well Completion Summary

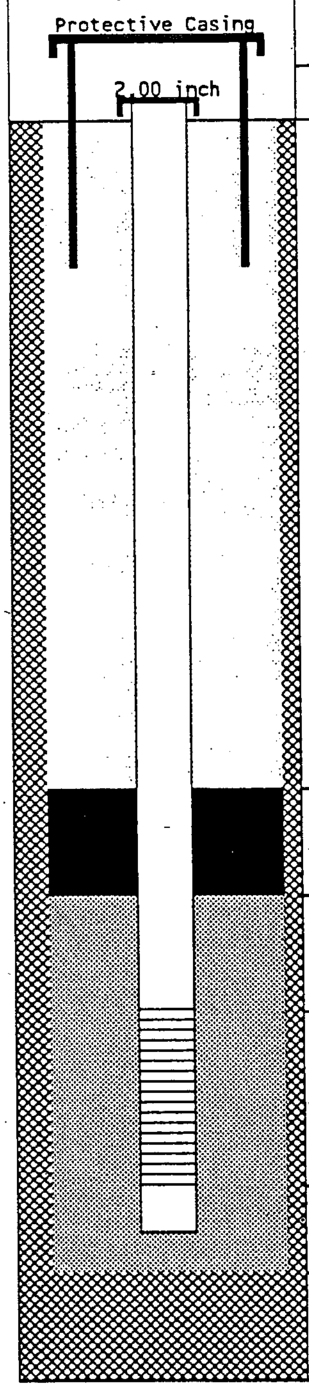
Roy F. WESTON, Inc.

CLIENT ELF ATOCHEM
SITE NAME

DRILLING FIRM
INSPECTOR B.W.B.

WELL ID MW11
START DATE 04/22/86
COMPLETION DATE 04/22/86

WATER LEVELS



DEPTH		ELEV.
2.20	TC	580.66
0.00	GS	578.46
1.00	BN	577.46
1.80	SP	576.66
2.80	SC	575.66
7.80	BS	570.66
7.80	TD	570.66

DRILLING SUMMARY

Driller
Drilling Fluid
Well Type SINGLE CASED SCREENED

WELL DESIGN CONSTRUCTION

Casing #1 Diameter: 2.00 inch Interval: 0.00 to 2.80 ft.
Type :

Stick Up Inner Casing: 2.20 ft. Protective Casing: 0.00 ft.

Casing Grout: OTHER Interval: 0.00 to 1.00 ft.

Seal Type: BENTONITE PELLETS Interval: 1.00 to 1.70 ft.

Sand Pack Type : MEDIUM-COARSE Interval: 1.80 to 7.80 ft.
Grain Size : MIXED Median Diameter:
Screen Diameter: 2.00 Interval: 2.80 to 7.80 ft.
Type : PVC Slots: inches

Silt Trap Interval: 0.00 to 0.00 ft.
Backfill Type : SAND Interval: 7.80 to 8.00 ft.

WELL DEVELOPMENT

Date / /
Method
Yield Purged Volume

COMMENTS

TC = Top of Casing
GS = Ground Surface
BN = Top Seal
SP = Top Sand Pack
SC = Top Screen
BS = Bottom Screen
TD = Total Depth
= Grout
= Seal
= Sand Pack
= Formation

Additional Comments:

NOTE: Well Diagram not to Scale

Elevations are feet above mean sea level

 01/06/94

Borehole Log

Roy F. WESTON, Inc.

CLIENT	:	ELF ATOCHEM	TOTAL DEPTH	:	8.00
SITE NAME	:		LOGGER	:	B.W.B.
WELL ID	:	MW11	DRILLING COMPANY	:	MCDOWELL
NORTHING	:	9726.9457 surveyed	DRILLING RIG	:	CME 55
EASTING	:	10232.4009 surveyed	DATE STARTED	:	04/22/86
ELEVATION	:	578.460 estimated	DATE COMPLETED	:	04/22/86

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
	0			Fill	GRAY-DK GRAY			6 9 9 5	HNU 0.0	Gravelly sandy ash fill; saturated at 1.3' with tan, white sludge material.
577	1									
576	2			Fill	GRAY-DK GRAY		SAT	3 3 3 4	HNU 0.0	Gravelly sandy ash fill with tan, white sludge material. Black silt on bottom of spoon.
575	3									
574	4			Sand	OLIVE GRAY		SAT	1 8 4 8	HNU 2.0	Fine sand; saturated.
573	5									
				Sand	OLIVE GRAY		SAT		HNU 2.0	Fine sand; saturated; with black stains.
				Sandy clay	GRAY, BROWN		MST		HNU 0.0	Mottled gray, brown sandy clay; moist; low to med plastic; trace coarse subround sand.
572	6			Sandy clay	GRAY, BROWN		MST	5 9 6 17	HNU 0.0	
571	7									
570	8									
569	9									
568	10									

BOREHOLE /WELL ID	SMP NUM	LTH NUM	LITHOLOGY INT. (FT BGS)		SAMPLING METHOD	SIZE GRAVEL	GRAVEL PCT.	SIZE SAND	SAND PCT	SILT PCT	CLAY PCT	ORGANIC PCT	ROCK TYPE	PLAST	SORT	STRENGTH	MOISTURE	STRAT UNIT
MW11	1	1	0.00	2.00	SPS		0		0	0	0	0						
MW11	2	1	2.00	4.00	SPS		0		0	0	0	0					SAT	
MW11	3	1	4.00	5.50	SPS		0	F	0	0	0	0					SAT	
MW11	3	2	5.50	5.80	SPS		0	F	0	0	0	0					SAT	
MW11	3	3	5.80	6.00	SPS		0	C	0	0	0	0		MOD			MST	
MW11	4	1	6.00	8.00	SPS		0	C	0	0	0	0		MOD			MST	

BOREHOLE ID : MW16 *SITE NAME/NO:* ELF ATOCHEM
BEGIN DATE : 07/11/93 *END DATE :* 07/12/93

LOGGER/COMPANY : M. DOLHANCEY

BOREHOLE COMPLETED IN (<O>verburden <B>edrock) : O

TOTAL DEPTH : 18.00 *DEPTH TO BEDROCK :* 0.00

BOREHOLE DIAMETER #1: 7.00
INTERVAL: 0.00 ft. to 18.00 ft. BGS
METHOD : HSA *FLUID :* NONE
BOREHOLE DIAMETER #2:
INTERVAL:
METHOD : *FLUID :*
BOREHOLE DIAMETER #3:
INTERVAL:
METHOD : *FLUID :*

DRILLING COMPANY : BOWSER-MORNER
DRILLER : G. VORE
DRILL RIG TYPE : MOBILE B-61

	ESTIMATED	*SURVEYED*
SURFACE ELEVATION :	577.290	
N. COORDINATE :	0.0000	9035.8756
E. COORDINATE :	0.0000	10739.9934

WELL PERMIT......(Y)es (N)o: N *PERMIT # :*

HOLE ABANDONED...(Y)es (N)o: N
WELL INSTALLED...(Y)es (N)o: Y
WELL CLUSTER.....(Y)es (N)o: N *No. OF WELLS :* 0
WELL NEST........(Y)es (N)o: N *No. OF WELLS :* 0
PUMPS INSTALLED..(Y)es (N)o: N

	TYPE	*DEPTH*
PURGE :		0.00
SAMPLE :		0.00

BOREHOLE TESTING
BOREHOLE GEOPHYSICS.....(Y)es (N)o: N
SLUG TESTS..............(Y)es (N)o: Y
PACKER TESTS............(Y)es (N)o: N
PUMPING TESTS...........(Y)es (N)o: N

COMMENTS :
Install shallow well MW16 - Geotech samples collected.

Well Completion Summary

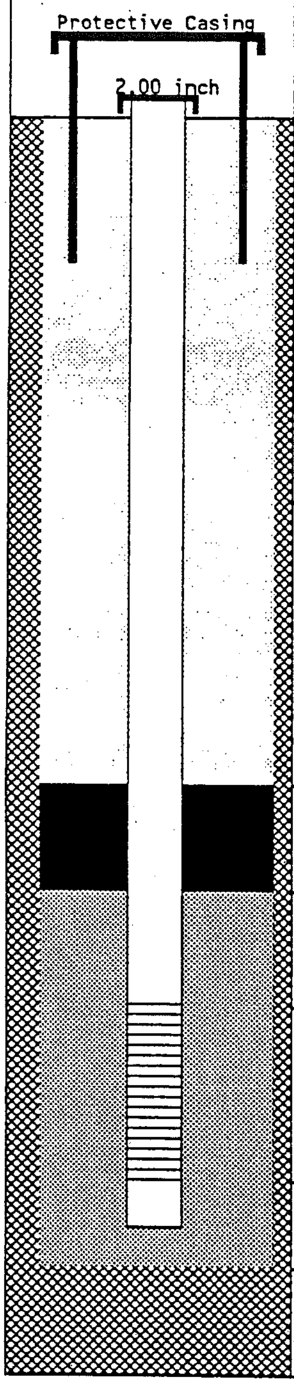
Roy F. WESTON, Inc.

CLIENT ELF ATOCHEM
SITE NAME

DRILLING FIRM BOWSER-MORNER
INSPECTOR M. DOLHANCEY

WELL ID MW16
START DATE 07/11/93
COMPLETION DATE 07/12/93

WATER LEVELS
4.57 FT (TOC) ON 07/28/93



DEPTH		ELEV.
2.00	TC	579.29
0.00	GS	577.29
4.00	BN	573.29
6.00	SP	571.29
8.00	SC	569.29
17.50	BS	559.79
18.00	TD	559.29

DRILLING SUMMARY

Driller G. VORE
Drilling Fluid NONE
Well Type SINGLE CASED SCREENED

WELL DESIGN CONSTRUCTION

Casing #1 Diameter: 2.00 **inch** **Interval:** 0.00 to 8.00 **ft.**
Type : STAINLESS

Stick Up Inner Casing: 2.00 **ft.** **Protective Casing:** 2.00 **ft.**

Casing Grout: CEMT/BENT **Interval:** 0.00 to 4.00 **ft.**

Seal Type: BENTONITE **Interval:** 4.00 to 6.00 **ft.**

Sand Pack Type : QUARTZ SAND **Interval:** 6.00 to 18.00 **ft.**
Grain Size : **Median Diameter:**
Screen Diameter: 2.00 **Interval:** 8.00 to 17.50 **ft.**
Type : STAINLESS **Slots:** 0.010 **inches**

Silt Trap Interval: 17.50 to 18.00 **ft.**
Backfill Type : **Interval:** 0.00 to 0.00 **ft.**

WELL DEVELOPMENT

Date 07/28/93
Method Bail, Pump and Surge
Yield .4 gpm **Purged Volume** 30 gal

COMMENTS

TC = Top of Casing
GS = Ground Surface
BN = Top Seal

SP = Top Sand Pack
SC = Top Screen
BS = Bottom Screen
TD = Total Depth

= Grout
= Seal
= Sand Pack
= Formation

Additional Comments:
Water level recorded from top of inner casing.

NOTE: Well Diagram not to Scale

Elevations are feet above mean sea level

01/06/94

Borehole Log

Roy F. WESTON, Inc.

CLIENT	:	ELF ATOCHEM	TOTAL DEPTH	:	18.00
SITE NAME	:		LOGGER	:	M. DOLHANCEY
WELL ID	:	MW16	DRILLING COMPANY	:	BOWSER-MORNER
NORTHING	:	9035.8756 surveyed	DRILLING RIG	:	MOBILE B-61
EASTING	:	10739.9934 surveyed	DATE STARTED	:	07/11/93
ELEVATION	:	577.290 estimated	DATE COMPLETED	:	07/12/93

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
			80	Fill	BLACK	LSE	DRY	5 7 8 8	OVA 0.0 OVM 0.0	Fill material - gravels, sands, some silt, black in color. GEOTECH sample collected (25 cm).
576	1									
				No Sample Recovered						
575	2		65	Fill	DK GRAY BROWN	SFT	MST	2 3 4 4	OVA 0.0	Dark grayish brown sand with dark yellowish brown mottles. GEOTECH samples collected (25 cm).
574	3									
				No Sample Recovered						
573	4		50	Fill	BLACK	LSE	WET	2 2 1 1	OVA 0.0	Gravelly sandy fill material; saturated. No sample collected.
572	5									
				No Sample Recovered						
571	6		75	Lean clay with sand, CL	BLACK	SFT	WET	1 1 1 1	OVA 4.4	Black silty clay with some sand and peat (organic layer). GEOTECH sample collected.
570	7									
				No Sample Recovered						
569	8		75	Lean clay with sand, CL	DK GRAY	FRM	WET	1 2 2 3	OVA 0.0	silty clay with some sand and little organics (roots). GEOTECH sample collected.
568	9									
				No Sample Recovered						
567	10		75	Silty sand, SM	DK GRAY	LSE	WET	2 3 4 5	OVA 0.0	Fine dark gray sand with some silt and organics (roots). GEOTECH sample collected.

CLIENT	: ELF ATOCHEM	TOTAL DEPTH	: 18.00
SITE NAME	:	LOGGER	: M. DOLHANCEY
WELL ID	: MW16	DRILLING COMPANY	: BOWSER-MORNER
NORTHING	: 9035.8756 surveyed	DRILLING RIG	: MOBILE B-61
EASTING	: 10739.9934 surveyed	DATE STARTED	: 07/11/93
ELEVATION	: 577.290 estimated	DATE COMPLETED	: 07/12/93

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Silty sand, SM	DK GRAY	LSE	WET		OVA 0.0	Fine dark gray sand with some silt and organics (roots). GEOTECH sample collected.
566	11									
				No Sample Recovered						
565	12		90	Poorly graded sand with silt, SP-SM	DK GRAY	LSE	WET	3 5 7 12	OVA 0.0	Fine dark gray sand grading toward more of a clay in bottom of spoon. GEOTECH sample collected.
564	13									
				No Sample Recovered						
563	14		90	Sandy silt with gravel, ML	DK GRAY	FRM	MST	12 16 18 24	OVA 0.0	Sandy silt/clay with some gravel; firm. GEOTECH sample collected.
562	15									
				No Sample Recovered						
561	16		65	Sandy lean clay with gravel, CL	DK GRAY	FRM	MST	5 9 150 16	OVA 0.0	Dark gray sand and silty/clay with some fine gravel; firm. GEOTECH sample collected (25 cm).
560	17									
				No Sample Recovered						
559	18									
558	19									
557	20									

BOREHOLE /WELL ID	SMP NUM	LTH NUM	LITHOLOGY INT. (FT BGS)		SAMPLING METHOD	SIZE GRAVEL	GRAVEL PCT.	SIZE SAND	SAND PCT	SILT PCT	CLAY PCT	ORGANIC PCT	ROCK TYPE	PLAST	SORT	STRENGTH	MOISTURE	STRAT UNIT
MW16	1	1	0.00	1.60	SSS	MF	30	CMF	50	20	0	0		NON	POR	LSE	DRY	
MW16	1	2	1.60	2.00	SSS		0		0	0	0	0						
MW16	2	1	2.00	3.30	SSS		0	F	100	0	0	0		NON	MOD	SFT	MST	
MW16	2	2	3.30	4.00	SSS		0		0	0	0	0						
MW16	3	1	4.00	5.40	SSS	MF	45	CMF	35	20	0	0		NON	POR	LSE	WET	
MW16	3	2	5.40	6.00	SSS		0		0	0	0	0						
MW16	4	1	6.00	7.50	SSS		0	F	15	30	40	15		MOD	WEL	SFT	WET	
MW16	4	2	7.50	8.00	SSS		0		0	0	0	0						
MW16	5	1	8.00	9.50	SSS		0	F	15	35	45	5		MOD	WEL	FRM	WET	
MW16	5	2	9.50	10.00	SSS		0		0	0	0	0						
MW16	6	1	10.00	11.50	SSS		0	F	80	10	5	5		NON	MOD	LSE	WET	
MW16	6	2	11.50	12.00	SSS		0		0	0	0	0						
MW16	7	1	12.00	13.80	SSS		0	F	90	5	5	0		NON	WEL	LSE	WET	
MW16	7	2	13.80	14.00	SSS		0		0	0	0	0						
MW16	8	1	14.00	15.80	SSS	F	15		20	35	30	0		LOW	MOD	FRM	MST	
MW16	8	2	15.80	16.00	SSS		0		0	0	0	0						
MW16	9	1	16.00	17.30	SSS	F	15		20	30	35	0		LOW	MOD	FRM	MST	
MW16	9	2	17.30	18.00	SSS		0		0	0	0	0						

BOREHOLE ID : MW109 SITE NAME/NO: ELF ATOCHEM
BEGIN DATE : 07/22/93 END DATE : 07/23/93

LOGGER/COMPANY : B. JAKUB

BOREHOLE COMPLETED IN (<O>verburden <B>edrock) : O

TOTAL DEPTH : 37.00 DEPTH TO BEDROCK : 0.00

BOREHOLE DIAMETER #1: 8.60
INTERVAL: 0.00 ft. to 23.00 ft. BGS
METHOD : CBT FLUID : WATER
BOREHOLE DIAMETER #2: 6.50
INTERVAL: 23.00 ft. to 37.00 ft. BGS
METHOD : CBT FLUID : WATER
BOREHOLE DIAMETER #3:
INTERVAL:
METHOD : FLUID :

DRILLING COMPANY : BOWSER-MORNER
DRILLER : B. YOUNG
DRILL RIG TYPE : BUCYRUS ERIE 22W

	ESTIMATED	SURVEYED
SURFACE ELEVATION :	577.080	
N. COORDINATE :	0.0000	9365.1567
E. COORDINATE :	0.0000	10935.1468

WELL PERMIT......(Y)es (N)o: N PERMIT # :

HOLE ABANDONED...(Y)es (N)o: N
WELL INSTALLED...(Y)es (N)o: Y
WELL CLUSTER.....(Y)es (N)o: Y No. OF WELLS : 3
WELL NEST........(Y)es (N)o: N No. OF WELLS : 0
PUMPS INSTALLED..(Y)es (N)o: N

	TYPE	DEPTH
PURGE :		0.00
SAMPLE :		0.00

BOREHOLE TESTING
BOREHOLE GEOPHYSICS.....(Y)es (N)o: N
SLUG TESTS..............(Y)es (N)o: Y
PACKER TESTS............(Y)es (N)o: N
PUMPING TESTS...........(Y)es (N)o: N

COMMENTS :
Intermediate well installed adjacent to MW209 and MW9.
Geotechnical samples collected including Shelby tubes.

Well Completion Summary

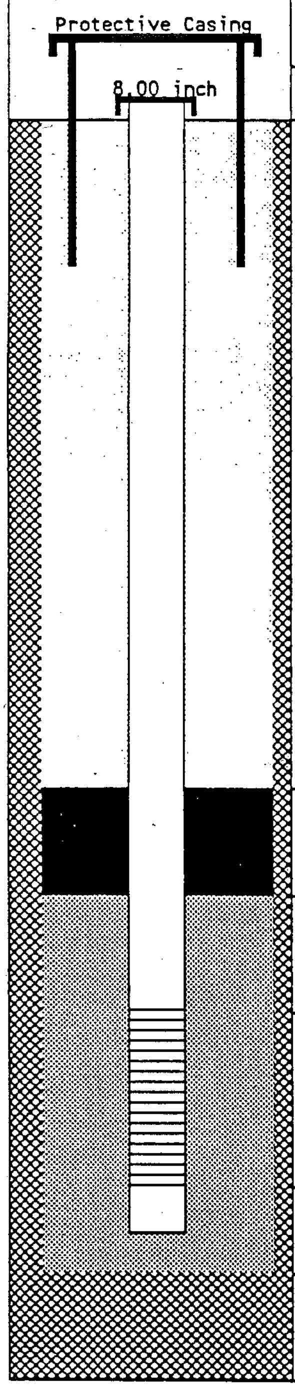
Roy F. WESTON, Inc.

CLIENT	ELF ATOCHEM	***DRILLING FIRM***	BOWSER-MORNER
SITE NAME		***INSPECTOR***	B. JAKUB

WELL ID	MW109
START DATE	07/22/93
COMPLETION DATE	07/23/93

WATER LEVELS

20.00 FT (TOC) ON 07/25/93



DEPTH		***ELEV.***
1.48	***TC***	578.56
0.00	***GS***	577.08
21.40	***BN***	555.68
24.50	***SP***	552.58
27.00	***SC***	550.08
37.00	***BS***	540.08
37.00	***TD***	540.08

DRILLING SUMMARY

Driller B. YOUNG
Drilling Fluid WATER
Well Type DOUBLE CASED SCREENED

WELL DESIGN CONSTRUCTION

Casing #1 Diameter: 2.00 ***inch*** ***Interval:*** 0.00 to 27.00 ***ft.***
Type : STAINLESS

Stick Up Inner Casing: 1.48 ***ft.*** ***Protective Casing:*** 2.00 ***ft.***

Casing Grout: CEMT/BENT ***Interval:*** 0.00 to 21.40 ***ft.***

Seal Type: BENTONITE ***Interval:*** 21.40 to 24.50 ***ft.***

Sand Pack Type : BEST SAND #5 ***Interval:*** 24.50 to 37.00 ***ft.***
Grain Size : UNIFORM ***Median Diameter:*** 1-2 mm
Screen Diameter: 2.00 ***Interval:*** 27.00 to 37.00 ***ft.***
Type : STAINLESS ***Slots:*** 0.010 ***inches***

Silt Trap Interval: 0.00 to 0.00 ***ft.***
Backfill Type : ***Interval:*** 0.00 to 0.00 ***ft.***

WELL DEVELOPMENT

Date 07/26/93
Method Bail
Yield ND gpm ***Purged Volume*** 9 gal

COMMENTS

TC = Top of Casing	SP = Top Sand Pack	= Grout
GS = Ground Surface	SC = Top Screen	= Seal
BN = Top Seal	BS = Bottom Screen	= Sand Pack
	TD = Total Depth	= Formation

Additional Comments:

Water levels recorded from top of inner casing.

NOTE: Well Diagram not to Scale

Elevations are feet above mean sea level

Borehole Log

Roy F. WESTON, Inc.

CLIENT	:	ELF ATOCHEM	TOTAL DEPTH	:	37.00
SITE NAME	:		LOGGER	:	B. JAKUB
WELL ID	:	MW109	DRILLING COMPANY	:	BOWSER-MORNER
NORTHING	:	9365.1567 surveyed	DRILLING RIG	:	BUCYRUS ERIE 22W
EASTING	:	10935.1468 surveyed	DATE STARTED	:	07/22/93
ELEVATION	:	577.080 estimated	DATE COMPLETED	:	07/23/93

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Interval Not Sampled						Cable tool interval. Fill material.
576	1									
575	2									
574	3									
573	4									
572	5									
571	6									
570	7									
569	8									
568	9									
567	10			Interval Not Sampled						

Borehole Log

Roy F. WESTON, Inc.

CLIENT	:	ELF ATOCHEM	TOTAL DEPTH	:	37.00
SITE NAME	:		LOGGER	:	B. JAKUB
WELL ID	:	MW109	DRILLING COMPANY	:	BOWSER-MORNER
NORTHING	:	9365.1567 surveyed	DRILLING RIG	:	BUCYRUS ERIE 22W
EASTING	:	10935.1468 surveyed	DATE STARTED	:	07/22/93
ELEVATION	:	577.080 estimated	DATE COMPLETED	:	07/23/93

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Interval Not Sampled						
566	11									
565	12									
564	13									
563	14									
562	15		100	Silt with sand, ML	GRAY	STF	MST	3 3 3 5	OVA 0.0 OVM 0.0	Oil sheen.
561	16									
560	17			Interval Not Sampled						
559	18									
558	19									
557	20		100	Silt with sand, ML	GRAY	FRM	MST	2 2 2 4		

Borehole Log

Roy F. WESTON, Inc.

CLIENT	:	ELF ATOCHEM	TOTAL DEPTH	:	37.00
SITE NAME	:		LOGGER	:	B. JAKUB
WELL ID	:	MW109	DRILLING COMPANY	:	BOWSER-MORNER
NORTHING	:	9365.1567 surveyed	DRILLING RIG	:	BUCYRUS ERIE 22W
EASTING	:	10935.1468 surveyed	DATE STARTED	:	07/22/93
ELEVATION	:	577.080 estimated	DATE COMPLETED	:	07/23/93

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Silt with sand, ML	GRAY	FRM	MST			
556	21									
555	22			Interval Not Sampled						Cable tool interval. Set casing to 23 ft.
554	23			Interval Not Sampled						Gray clayey silt as above Cable tool interval.
553	24									
552	25									
551	26									
550	27									
549	28									
548	29									
547	30									

Borehole Log

Roy F. WESTON, Inc.

CLIENT	: ELF ATOCHEM		TOTAL DEPTH	:	37.00
SITE NAME	:		LOGGER	:	B. JAKUB
WELL ID	: MW109		DRILLING COMPANY	:	BOWSER-MORNER
NORTHING	: 9365.1567 surveyed		DRILLING RIG	:	BUCYRUS ERIE 22W
EASTING	: 10935.1468 surveyed		DATE STARTED	:	07/22/93
ELEVATION	: 577.080 estimated		DATE COMPLETED	:	07/23/93

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Interval Not Sampled						Gray clayey silt as above Cable tool interval.
546	31									
545	32									
544	33									
543	34									
542	35									
541	36									
540	37									
539	38									
538	39									
537	40									

BOREHOLE /WELL ID	SMP NUM	LTH NUM	LITHOLOGY INT. (FT BGS)		SAMPLING METHOD	SIZE GRAVEL	GRAVEL PCT.	SIZE SAND	SAND PCT	SILT PCT	CLAY PCT	ORGANIC PCT	ROCK TYPE	PLAST	SORT	STRENGTH	MOISTURE	STRAT UNIT
MW109	1	1	0.00	10.00	NS		0		0	0	0	0						
MW109	2	1	10.00	15.00	NS		0		0	0	0	0						
MW109	3	1	15.00	17.00	SSS	F	2	MF	13	80	5	0		LOW	NA	STF	MST	
MW109	4	1	17.00	20.00	NS		0		0	0	0	0						
MW109	5	1	20.00	22.00	SSS	F	1	MF	9	80	10	0				FRM	MST	
MW109	6	1	22.00	23.00	NS		0		0	0	0	0						
MW109	7	1	23.00	37.00	NS		0		0	0	0	0						

BOREHOLE ID : MW209 *SITE NAME/NO:* ELF ATOCHEM
BEGIN DATE : 07/09/93 *END DATE :* 07/22/93

LOGGER/COMPANY : M. DOLHANCEY

BOREHOLE COMPLETED IN (<O>verburden <B>edrock) : B

TOTAL DEPTH : 59.00 *DEPTH TO BEDROCK :* 51.00

BOREHOLE DIAMETER #1: 10.50
INTERVAL: 0.00 ft. to 23.00 ft. BGS
METHOD : CBT *FLUID :* WATER
BOREHOLE DIAMETER #2: 8.50
INTERVAL: 23.00 ft. to 59.00 ft. BGS
METHOD : CBT *FLUID :* WATER
BOREHOLE DIAMETER #3:
INTERVAL:
METHOD : *FLUID :*

DRILLING COMPANY : BOWSER-MORNER
DRILLER : B. YOUNG
DRILL RIG TYPE : BUCYRUS ERIE 22W

	ESTIMATED	*SURVEYED*
SURFACE ELEVATION :	578.270	
N. COORDINATE :	0.0000	9354.8257
E. COORDINATE :	0.0000	10951.1416

WELL PERMIT......(Y)es (N)o: N *PERMIT # :*

HOLE ABANDONED...(Y)es (N)o: N
WELL INSTALLED...(Y)es (N)o: Y
WELL CLUSTER.....(Y)es (N)o: Y *No. OF WELLS :* 3
WELL NEST........(Y)es (N)o: N *No. OF WELLS :* 0
PUMPS INSTALLED..(Y)es (N)o: N

	TYPE	*DEPTH*
PURGE :		0.00
SAMPLE :		0.00

BOREHOLE TESTING
BOREHOLE GEOPHYSICS.....(Y)es (N)o: N
SLUG TESTS..............(Y)es (N)o: Y
PACKER TESTS............(Y)es (N)o: N
PUMPING TESTS...........(Y)es (N)o: N

COMMENTS :
Installation of MW209 adjacent to MW109 and MW9.
Geotechnical samples collected, including Shelby tubes.

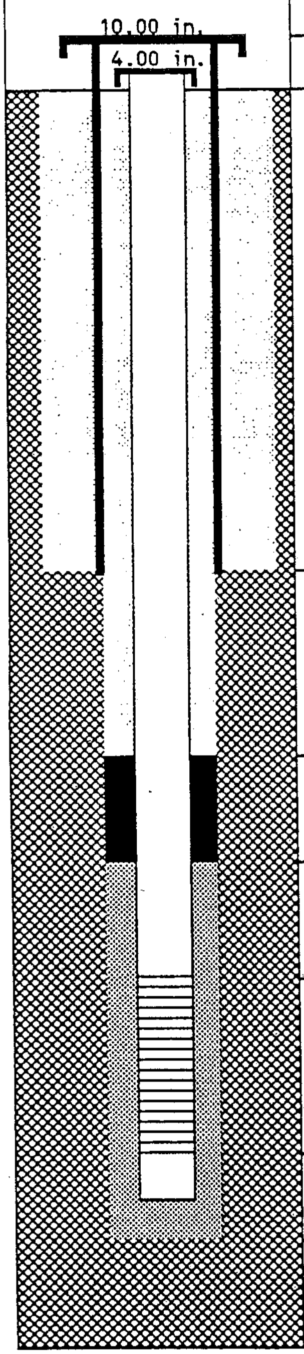
Well Completion Summary

Roy F. WESTON, Inc.

CLIENT	ELF ATOCHEM	**DRILLING FIRM**	BOWSER-MORNER
SITE NAME		**INSPECTOR**	M. DOLHANCEY

WELL ID	MW209
START DATE	07/09/93
COMPLETION DATE	07/22/93

WATER LEVELS
12.93 FT (TOC) ON 07/27/93



DEPTH		ELEV.
1.46	TC	579.73
0.00	GS	578.27
23.00	OC	555.27
44.40	BN	533.87
46.40	SP	531.87
47.60	SC	530.67
58.80	BS	519.47
59.00	TD	519.27

DRILLING SUMMARY

Driller B. YOUNG
Drilling Fluid WATER
Well Type DOUBLE CASED SCREENED

WELL DESIGN CONSTRUCTION

Casing #1 Diameter: 4.00 **inch** — **Interval:** 0.00 to 47.00 **ft.**
Type : STAINLESS
Casing #2 Diameter: 10.00 **inch** — **Interval:** 0.00 to 23.00 **ft.**
Type : LOW CARBON

Stick Up Inner Casing: 1.46 **ft.** — **Outer Casing:** 2.00 **ft.**

Casing Grout: CEMT/BENT — **Interval:** 0.00 to 44.50 **ft.**

Seal Type: BENTONITE PELLETS — **Interval:** 44.40 to 46.40 **ft.**

Sand Pack Type : QUARTZ SAND — **Interval:** 46.40 to 59.00 **ft.**
Grain Size : UNIFORM — **Median Diameter:** 5
Screen Diameter: 4.00 — **Interval:** 47.60 to 58.80 **ft.**
Type : STAINLESS — **Slots:** 0.010 **inches**

Silt Trap Interval: 0.00 to 0.00 **ft.**
Backfill Type : — **Interval:** 0.00 to 0.00 **ft.**
Top of Bedrock :

WELL DEVELOPMENT

Date 07/27/93
Method Pump and Surge
Yield 5 gpm — **Purged Volume** 485 gal

COMMENTS

TC = Top of Casing
GS = Ground Surface
BN = Top Seal
OC = Outer Casing
SP = Top Sand Pack
SC = Top Screen
BS = Bottom Screen
TD = Total Depth
= Grout
= Seal
= Sand Pack
= Formation

Additional Comments:
Water levels recorded from top of inner casing.

NOTE: Well Diagram not to Scale

Elevations are feet above mean sea level

01/06/94

CLIENT	: ELF ATOCHEM	TOTAL DEPTH	: 59.00
SITE NAME	:	LOGGER	: M. DOLHANCEY
WELL ID	: MW209	DRILLING COMPANY	: BOWSER-MORNER
NORTHING	: 9354.8257 surveyed	DRILLING RIG	: BUCYRUS ERIE 22W
EASTING	: 10951.1416 surveyed	DATE STARTED	: 07/09/93
ELEVATION	: 578.270 estimated	DATE COMPLETED	: 07/22/93

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
			50	Fill	V DK GRAY	LSE	DRY	2 3 1 2	OVM 0.0 OVA 0.0	Very dark gray fill material; not sampled.
577	1			No Sample Recovered						
576	2		50	Fill	V DK GRAY	SFT	WET	2 2 3 5	OVM 137.0 OVA 100.0	Very dark gray fill material.
575	3			No Sample Recovered						
574	4		90	Fill	BLACK	FRM	DRY	5 7 6 6	OVA 10.0 OVM 0.0	Black fill material (coal fragments and material resembling charred wood). GEOTECH sample collected.
573	5									
				No Sample Recovered						
572	6		50	Fill	BLACK	LSE	WET	8 8 2 1	OVA 4.0 OVM 0.0	Black silty sandy fill material. GEOTECH sample collected.
571	7			No Sample Recovered						
570	8		85	Poorly graded sand, SP	GRAY BROWN	SFT	SAT	8 3 3 3	OVA 10.0 OVM 0.0	Dark grayish brown very fine sand. Upper 3" of spoon is slightly stained GEOTECH sample collected.
569	9									
				No Sample Recovered						
568	10		50	Poorly graded sand, SP	DK GRAY BROWN	SFT	SAT	8 8 3 2	OVM 0.0	Dark grayish brown fine sand with some silt.

Borehole Log

Roy F. WESTON, Inc.

CLIENT	: ELF ATOCHEM		TOTAL DEPTH	: 59.00
SITE NAME	:		LOGGER	: M. DOLHANCEY
WELL ID	: MW209		DRILLING COMPANY	: BOWSER-MORNER
NORTHING	: 9354.8257 surveyed		DRILLING RIG	: BUCYRUS ERIE 22W
EASTING	: 10951.1416 surveyed		DATE STARTED	: 07/09/93
ELEVATION	: 578.270 estimated		DATE COMPLETED	: 07/22/93

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Poorly graded sand, SP	DK GRAY BROWN	SFT	SAT		OVM 0.0	Dark grayish brown fine sand with some silt.
567	11			No Sample Recovered						
566	12		50	Poorly graded sand with silt, SP-SM	DK GRAY BROWN	SFT	SAT	2 2 2 6	OVM 0.0	Dark grayish borwn fine sand with some silt.
565	13			No Sample Recovered						
564	14		100	Poorly graded sand with silt, SP-SM	DK GRAY BROWN	SFT	SAT	2 2 2 2	OVM 0.0	Dark grayish brown fine sand with some silt and clay.
563	15									
562	16		60	Sandy silt, ML	DK GRAY	FRM	MST	2 3 4 6	OVA 1.8	Dark gray sandy silt/clay with some gravel; very firm.
561	17			No Sample Recovered						
560	18			No Sample Recovered						CBT interval.
				No Sample Recovered						Shelby tube driven - lost entire tube in hole. No recovery.
559	19									
558	20									

CLIENT	: ELF ATOCHEM	TOTAL DEPTH	: 59.00
SITE NAME	:	LOGGER	: M. DOLHANCEY
WELL ID	: MW209	DRILLING COMPANY	: BOWSER-MORNER
NORTHING	: 9354.8257 surveyed	DRILLING RIG	: BUCYRUS ERIE 22W
EASTING	: 10951.1416 surveyed	DATE STARTED	: 07/09/93
ELEVATION	: 578.270 estimated	DATE COMPLETED	: 07/22/93

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				No Sample Recovered						Shelby tube driven - lost entire tube in hole. No recovery.
				No Sample Recovered						CBT interval.
557	21			No Sample Recovered				6 9 9 12		No recovery.
556	22									
555	23		70	Sandy lean clay, CL	DK GRAY	FRM	MST	2 2 2 3	OVA 0.0	Dark gray silt/clay with gravel.
554	24									
				No Sample Recovered						
553	25			Interval Not Sampled						CBT interval.
				No Sample Recovered						Drove shelby tube - no recovery.
552	26									
551	27									
				Interval Not Sampled						CBT interval.
550	28		75	Entire Interval Sampled					ND 0.0	Shelby tube collected.
549	29									
				No Sample Recovered						
548	30			Interval Not Sampled					OVM 0.0	CBT interval.

CLIENT	:	ELF ATOCHEM	TOTAL DEPTH	:	59.00
SITE NAME	:		LOGGER	:	M. DOLHANCEY
WELL ID	:	MW209	DRILLING COMPANY	:	BOWSER-MORNER
NORTHING	:	9354.8257 surveyed	DRILLING RIG	:	BUCYRUS ERIE 22W
EASTING	:	10951.1416 surveyed	DATE STARTED	:	07/09/93
ELEVATION	:	578.270 estimated	DATE COMPLETED	:	07/22/93

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Interval Not Sampled					OVM 0.0	CBT interval.
547	31									
546	32									
545	33									
544	34									
543	35			No Sample Recovered						Drove Shelby tube - no recovery.
542	36									
541	37			Interval Not Sampled						
540	38			No Sample Recovered						No recovery in spoon.
539	39									
538	40			Interval Not Sampled						CBT interval.

Borehole Log | **Roy F. WESTON, Inc.**

CLIENT	:	ELF ATOCHEM	TOTAL DEPTH	:	59.00
SITE NAME	:		LOGGER	:	M. DOLHANCEY
WELL ID	:	MW209	DRILLING COMPANY	:	BOWSER-MORNER
NORTHING	:	9354.8257 surveyed	DRILLING RIG	:	BUCYRUS ERIE 22W
EASTING	:	10951.1416 surveyed	DATE STARTED	:	07/09/93
ELEVATION	:	578.270 estimated	DATE COMPLETED	:	07/22/93

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Interval Not Sampled						CBT interval.
537	41			No Sample Recovered						Drove Shelby tube - no recovery.
536	42									
535	43			Interval Not Sampled						CBT interval.
			90	Entire Interval Sampled						Shelby tube collected.
534	44									
533	45			Interval Not Sampled						CBT interval.
532	46									
531	47									
530	48									
529	49									
528	50		90	Fat clay with sand, CH	DK GRAY	SFT	WET	3 7 3 8	OVM 0.0	Soft dark gray clay with some sand, silt and gravel.

Borehole Log *Roy F. WESTON, Inc.*

CLIENT	: ELF ATOCHEM		TOTAL DEPTH	: 59.00	
SITE NAME	:		LOGGER	: M. DOLHANCEY	
WELL ID	: MW209		DRILLING COMPANY	: BOWSER-MORNER	
NORTHING	: 9354.8257 surveyed		DRILLING RIG	: BUCYRUS ERIE 22W	
EASTING	: 10951.1416 surveyed		DATE STARTED	: 07/09/93	
ELEVATION	: 578.270 estimated		DATE COMPLETED	: 07/22/93	

ELEVATION	DEPTH	MATERIAL	% RECOVERY	CLASSIFICATION	COLOR	STRENGTH	MOISTURE	BLOW COUNT	FIELD INSTRUMENT READING	COMMENTS
				Fat clay with sand, CH	DK GRAY	SFT	WET		OVM 0.0	Soft dark gray clay with some sand, silt and gravel.
527	51			Poorly graded gravel with clay, GP-GC		STF	WET		OVM 0.0	Angular gravel - bedrock (limestone) fragments.
				No Sample Recovered						
526	52			Interval Not Sampled						CBT interval. Limestone cuttings throughout interval.
525	53									
524	54									
523	55									
			15	Limestone				100 0 0 0		Fragments of limestone layering and small vesicles apparent. At 56.6 ft batter cut-tings comprised of round-ed gravel frags, dk in color % pulverized limstn
			15	No Sample Recovered						
522	56									
521	57									
				Limestone						CBT interval-lith logged from cuttings. Limestone fragments, some gravel and sand in cuttings.
520	58									
519	59									
518	60									

BOREHOLE /WELL ID	SMP NUM	LTH NUM	LITHOLOGY INT. (FT BGS)		SAMPLING METHOD	SIZE GRAVEL	GRAVEL PCT.	SIZE SAND	SAND PCT	SILT PCT	CLAY PCT	ORGANIC PCT	ROCK TYPE	PLAST	SORT	STRENGTH	MOISTURE	STRAT UNIT
MW209	1	1	0.00	1.00	SSS	F	25	CMF	60	10	0	5		NON	POR	LSE	DRY	
MW209	1	2	1.00	2.00	SSS		0		0	0	0	0						
MW209	2	1	2.00	3.00	SSS	F	25	CMF	60	15	0	0		NON	POR	SFT	WET	
MW209	2	2	3.00	4.00	SSS		0		0	0	0	0						
MW209	3	1	4.00	5.80	SSS	F	10	CMF	10	5	0	75		NON	MOD	FRM	DRY	
MW209	3	2	5.80	6.00	SSS		0		0	0	0	0						
MW209	4	1	6.00	7.00	SSS	F	5	MF	25	20	0	50		NON	POR	LSE	WET	
MW209	4	2	7.00	8.00	SSS		0		0	0	0	0						
MW209	5	1	8.00	9.70	SSS		0	F	100	0	0	0		NON	WEL	SFT	SAT	
MW209	5	2	9.70	10.00	SSS		0		0	0	0	0						
MW209	6	1	10.00	11.00	SSS		0	F	95	5	0	0		NON	WEL	SFT	SAT	
MW209	6	2	11.00	12.00	SSS		0		0	0	0	0						
MW209	7	1	12.00	13.00	SSS		0	F	90	10	0	0		NON	WEL	SFT	SAT	
MW209	7	2	13.00	14.00	SSS		0		0	0	0	0						
MW209	8	1	14.00	16.00	SSS		0	F	90	5	5	0		NON	WEL	SFT	SAT	
MW209	6	1	16.00	17.20	SSS	F	10		25	35	30	0		LOW	MOD	FRM	MST	
MW209	6	2	17.20	18.00	SSS		0		0	0	0	0						
MW209	10	1	18.00	18.50	CTS		0		0	0	0	0						
MW209	11	1	18.50	20.50	STS		0		0	0	0	0						
MW209	12	1	20.50	21.00	CTS		0		0	0	0	0						
MW209	13	1	21.00	23.00	SSS		0		0	0	0	0						
MW209	14	1	23.00	24.40	DDD	F	10	F	20	30	40	0		MOD	MOD	FRM	MST	
MW209	14	2	24.40	25.00	SSS		0		0	0	0	0						
MW209	15	1	25.00	25.50	NS		0		0	0	0	0						
MW209	16	1	25.50	27.50	STS		0		0	0	0	0						
MW209	17	1	27.50	28.00	NS		0		0	0	0	0						
MW209	19	1	28.00	29.50	STS		0		0	0	0	0						
MW209	19	2	29.50	30.00	STS		0		0	0	0	0						
MW209	20	1	30.00	35.00	NS		0		0	0	0	0						
MW209	21	1	35.00	37.00	STS		0		0	0	0	0						
MW209	22	1	37.00	38.00	NS		0		0	0	0	0						
MW209	23	1	38.00	40.00	SSS		0		0	0	0	0						
MW209	24	1	40.00	41.00	NS		0		0	0	0	0						
MW209	25	1	41.00	43.00	STS		0		0	0	0	0						
MW209	26	1	43.00	43.50	NS		0		0	0	0	0						

BOREHOLE /WELL ID	SMP NUM	LTH NUM	LITHOLOGY INT. (FT BGS)		SAMPLING METHOD	SIZE GRAVEL	GRAVEL PCT.	SIZE SAND	SAND PCT	SILT PCT	CLAY PCT	ORGANIC PCT	ROCK TYPE	PLAST	SORT	STRENGTH	MOISTURE	STRAT UNIT
MW209	27	1	43.50	45.50	STS		0		0	0	0	0						
MW209	28	1	45.50	50.00	NS		0		0	0	0	0						
MW209	29	1	50.00	51.00	SSS	F	5	F	15	20	60	0		HGH	MOD	SFT	WET	
MW209	29	2	51.00	51.80	SSS	M	90		0	0	10	0		NON	WEL	STF	WET	
MW209	29	3	51.80	52.00	SSS		0		0	0	0	0						
MW209	30	1	52.00	55.50	NS		0		0	0	0	0						
MW209	31	1	55.50	55.80	SSS		0		0	0	0	0						
MW209	31	2	55.80	57.50	SSS		0		0	0	0	0						
MW209	32	1	57.50	59.00	CTS		0		0	0	0	0						

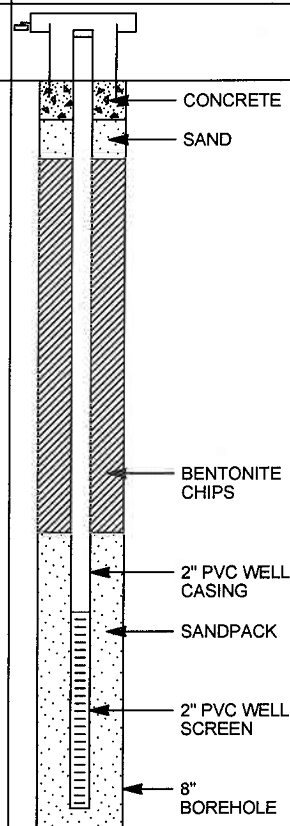
STRATIGRAPHIC AND INSTRUMENTATION LOG (OVERBURDEN)

PROJECT NAME: ARKEMA-EAST PLANT SITE (FORMER
PROJECT NUMBER: 14027-14
CLIENT: ARKEMA
LOCATION: RIVERVIEW, MICHIGAN

HOLE DESIGNATION: MW-025
DATE COMPLETED: August 14, 2006
DRILLING METHOD: GEOPROBE/HSA
FIELD PERSONNEL: E. VARNAS

DEPTH ft BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	DEPTH ft BGS
	TOP OF CASING	581.11
0–1.00	SW-SANDS (FILL), trace vegetation, trace fine gravel, loose to compact, medium to coarse grains, well graded, brown, dry - larger gravel (0.3 to 0.66 ft) at 0.3ft BGS	0.66 1.00
	SP-SANDS (FILL), w/red brick, loose to compact, fine grains, poorly graded, black, moist	
	SW-SANDS (FILL), trace fine/medium gravel, trace red brick, loose to compact, fine to medium grains, well graded, dark brown, moist - light gray, dry fines w/ medium gravel (3.8 to 4.5 ft) at 3.8ft BGS	5.00
	SW-SANDS (FILL), trace red brick, trace fine gravel, trace stone chips, loose to compact, medium grains, well graded, black, wet (9.0 to 10.0 ft. and 14.5 to 15.0 ft., odor, sheen, black) - more stone chips, trace limestone in chips, very angular at 13.5ft BGS	
18	CL-CLAYS, trace fine subangular gravel, medium plasticity, gray, very moist	18.00
20	END OF BOREHOLE @ 20.0ft BGS	20.00

MONITORIN WELL



WELL DETAILS
Screened interval:
13.50 to 18.50ft BGS
Length: 5ft
Diameter: 2in
Slot Size: 0.010
Material: PVC
Sand Pack:
11.50 to 19.00ft BGS
Material: FILTER PACK

SAMPLE

NUMBER	INTERVAL	REC (%)	'N' VALUE	PID (ppm)
1GP		70		0.8
2GP		50		31.2
3GP		50		27.5
4GP		90		21.5

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

Attachment B

Cross-Sectional Diagrams

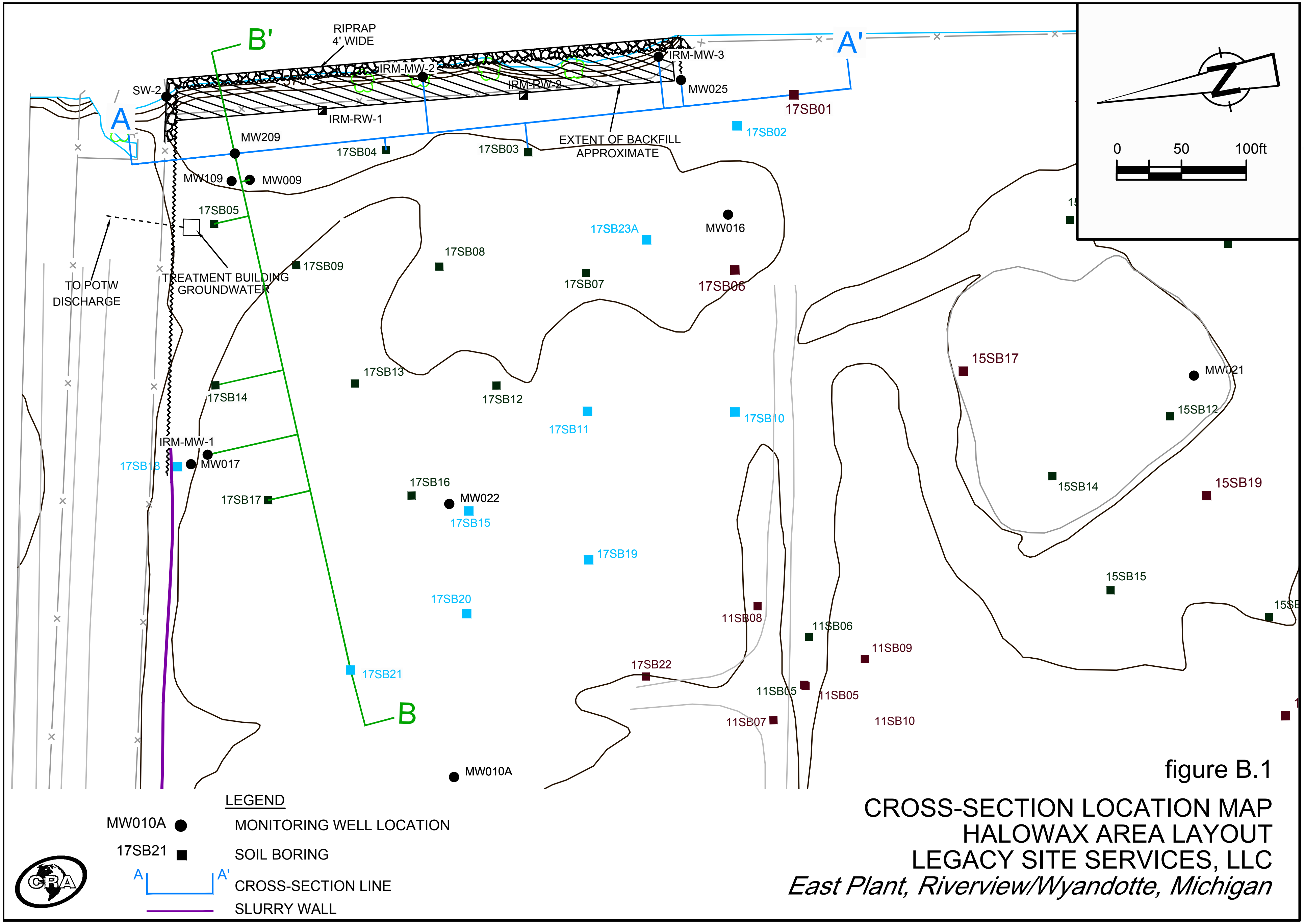


figure B.1

CROSS-SECTION LOCATION MAP
HALOWAX AREA LAYOUT
LEGACY SITE SERVICES, LLC
East Plant, Riverview/Wyandotte, Michigan

018224-05(BURY006)GN-DE002 MAR 26/2015

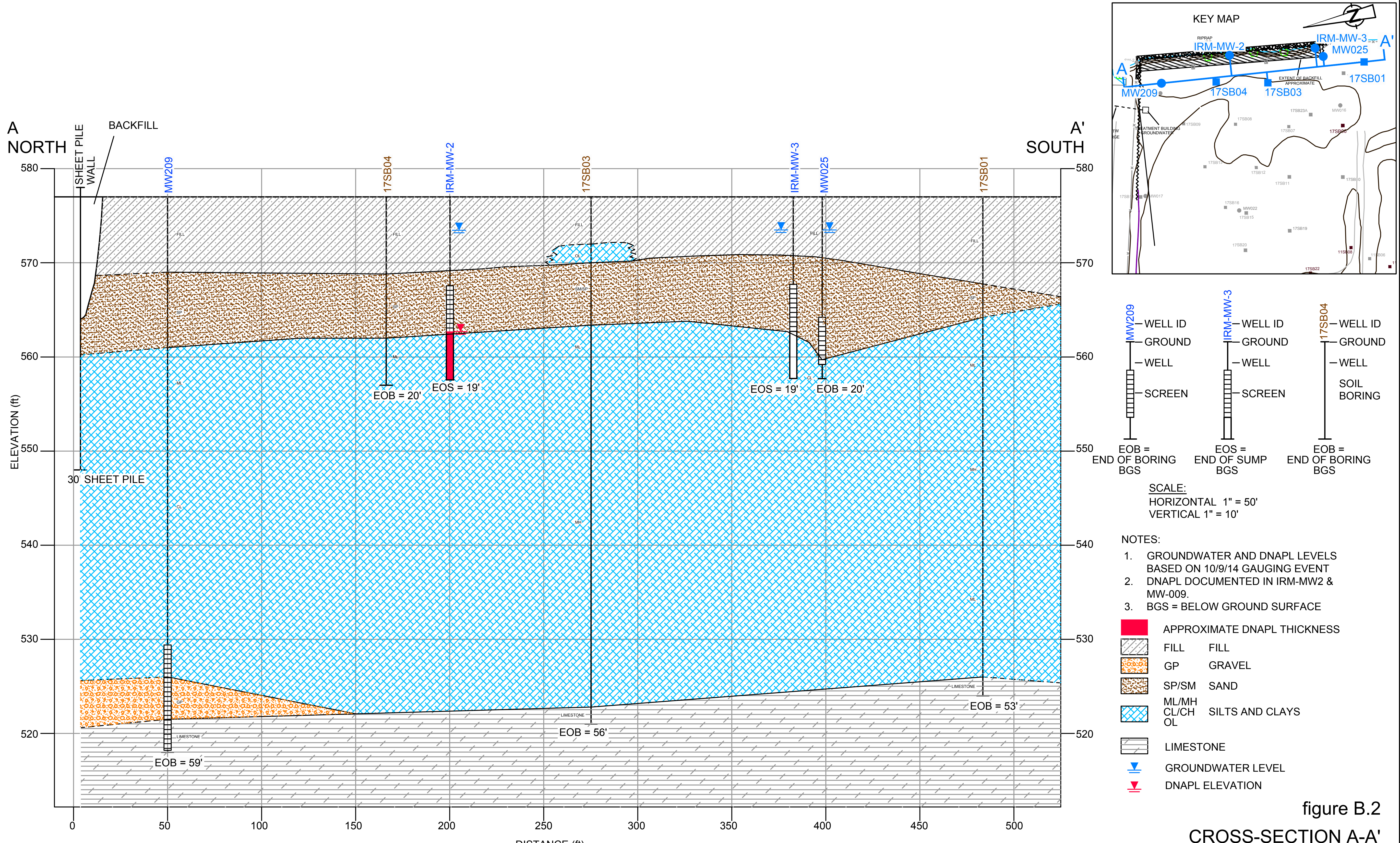
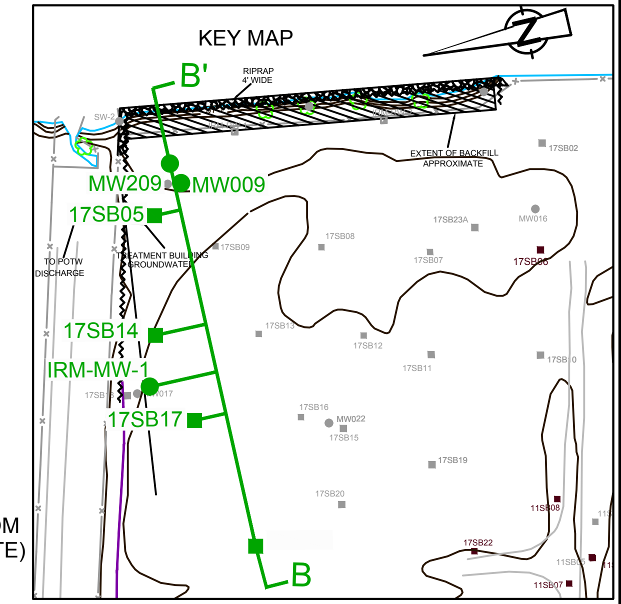
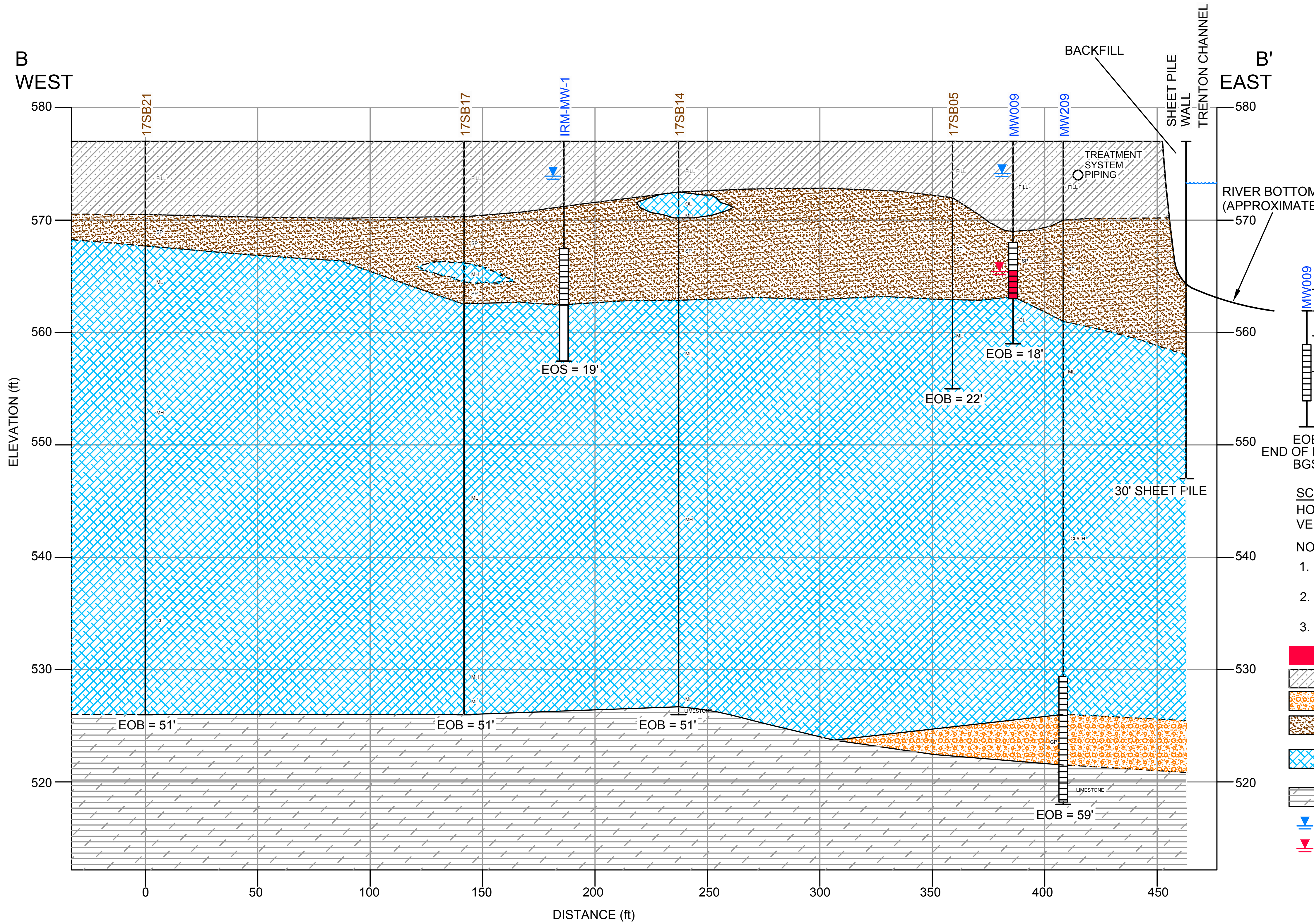


figure B.2

CROSS-SECTION A-A'
HALOWAX AREA LAYOUT
LEGACY SITE SERVICES, LLC
East Plant, Riverview/Wyandotte, Michigan

018224-05(BURY006)GN-DE003 MAR 26/2015





MW009 — WELL ID, GROUND, WELL, SCREEN; EOB = END OF BORING BGS

IRM-MW-1 — WELL ID, GROUND, WELL, SCREEN; EOS = END OF SUMP BGS

17SB17 — WELL ID, GROUND, WELL, SOIL BORING; EOB = END OF BORING BGS

SCALE:
HORIZONTAL 1" = 50'
VERTICAL 1" = 10'

NOTES:
1. GROUNDWATER AND DNAPL LEVELS BASED ON 10/9/14 GAUGING EVENT
2. DNAPL DOCUMENTED IN IRM-MW2 & MW-009.
3. BGS = BELOW GROUND SURFACE

	APPROXIMATE DNAPL THICKNESS	
	FILL	FILL
	GP	GRAVEL
	SP/SM	SAND
	ML/MH CL/CH OL	SILTS AND CLAYS
	LIMESTONE	
	GROUNDWATER LEVEL	
	DNAPL ELEVATION	

figure B.3

CROSS-SECTION B-B'
HALOWAX AREA LAYOUT
LEGACY SITE SERVICES, LLC
East Plant, Riverview/Wyandotte, Michigan

CRA

018224-05(BURY006)GN-DE003 MAR 26/2015

Attachment C

Standard Operating Procedures

CRA FIELD TRAINING MANUAL

SECTION 8.0:

FLUID LEVEL MONITORING STANDARD OPERATING PROCEDURES

- **GROUNDWATER/ RESIDENTIAL**
- **SURFACE WATER**

(FLD-0104)

JUNE 2008
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Revision 0 - June 3, 2008

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LIST OF FORMS

LIST OF QUALITY SYSTEM FORMS

8.0 FLUID LEVEL MONITORING STANDARD OPERATING PROCEDURES

8.1 INTRODUCTION

Fluid level monitoring within groundwater monitoring wells, residential wells, and surface water bodies are conducted in order to characterize the groundwater and surface water flow characteristics and interactions at a site. Standard Operating Procedures (SOPs) are presented herein for the collection of fluid levels from:

- monitoring wells;
- residential wells; and
- surface water bodies.

This guideline is not intended to provide the basis for designing a fluid level monitoring program, but instead assumes that a groundwater and/or surface water monitoring program has already been designed. It is also assumed that a site-specific Work Plan has been established and that a CRA representative is preparing to mobilize to the site.

Groundwater and surface water monitoring procedures vary from project to project due to:

- different chemicals of concern;
- different guidance provided by local, provincial/state, and/or federal regulatory agencies with jurisdiction at the site; and
- the specific objectives of the project.

It is essential that all groundwater, residential, and surface water fluid level monitoring activities are completed properly. Therefore, the CRA representative must carefully review the Work Plan requirements. The primary goal of groundwater, residential, and surface water fluid level monitoring is the collection of fluid level data representative of the hydrostratigraphic unit and/or surface water body. It is necessary to use appropriate monitoring techniques to collect representative data that provide reliable and reproducible results in accordance with the Work Plan and all relevant regulations.

The remainder of this section is organized as follows:

- Section 8.2 Background
- Section 8.3 Planning and Preparation
- Section 8.4 Safety and Health
- Section 8.5 Quality Assurance/Quality Control
- Section 8.6 Equipment Decontamination
- Section 8.7 Field Procedures for Groundwater/Residential/Leachate Fluid Level Monitoring
- Section 8.8 Field Procedures for Surface Water Fluid Level Monitoring

- Section 8.9 Follow-Up Activities
- Section 8.10 References

8.2 BACKGROUND

The measurement of fluid levels (groundwater or phase-separated compounds) in monitoring wells, piezometers, extraction wells, and/or boreholes is required in geotechnical, hydrogeologic, and waste management investigations to determine the presence and condition of the groundwater, or the presence and thickness of phase-separated compounds. Water level measurements (hydraulic head) are used to determine: hydraulic gradients and the direction of groundwater flow; the effectiveness of groundwater extraction systems; and the volume of water required for well purging prior to groundwater sampling. The measurement of the thickness of phase-separated compounds provides a qualitative (not quantitative) monitoring of this severe form of contamination.

In order to provide reliable data, water levels must be collected over as short a period of time as possible. Barometric pressure can affect groundwater levels and, therefore, observation of significant weather changes during the period of water level measurements must be noted. Tidal fluctuations, navigation controls on rivers, rainfall events and groundwater pumping can also affect groundwater and surface water levels. Personnel collecting water level data must note if any of these controls are in effect during the groundwater level collection period. Due to possible changes during the groundwater level collection period, it is imperative that the time of data collection at each station be accurately recorded.

In conjunction with groundwater level measurements, surface water (e.g., ponds, lakes, rivers, and lagoons) must also be monitored. This information is critical to understanding the hydrogeologic setting of the site and, most importantly, how contaminants may move beneath the site.

A number of devices are used by CRA to collect water level measurements. Typical devices used are:

- calibrated electronic water level indicator (e.g., Solinst, Heron, or Slope Indicator);
- measuring tape/plopper; and
- pressure transducer and datalogger (generally for pumping tests and long-term monitoring).

Devices typically used by CRA to measure phase-separated compounds are:

- oil/water interface probe;
- clear "bottom loading" bailer; and
- weighted cotton string or cord.

The pressure transducers and oil/water interface probes have manuals which describe their use. This SOP will focus on an overview of the use of this equipment and other methods which have more widespread use in fluid level measurement.

Since many decisions concerning the distribution, transport, and remediation of groundwater contamination will be made on the basis of the fluid level monitoring, the accuracy of the measurements made at an appropriate level of precision is very important. Typically, the precision required is ±0.01 foot (±1 mm) and the majority of CRA's measuring devices are calibrated to this precision level. To ensure accuracy, double check all fluid level readings; it is very easy to misread a tape or transpose figures when recording data.

8.3 PLANNING AND PREPARATION

Prior to measuring fluid levels:

1. Review the Work Plan, project documents, and Site-Specific Health and Safety Plan (HASP) with the Project Coordinator.
2. Review the Quality Assurance Project Plan (QAPP) with the Project Coordinator and Project Chemist to determine Quality Assurance/Quality Control (QA/QC) and decontamination requirements.
3. Complete a Field Equipment Requisition Form (QSF-014). Assemble all equipment and supplies required in accordance with the Water Level Measurement Equipment and Supply Checklist (Form SP-10). A Project Planning Completion and Follow-Up Checklist (Form SP-02) should be used for guidance throughout the project.
4. Assemble the site plan, well depths, and previous measurements. Determine the exact number of points (wells and surface water levels to be measured).
5. Obtain all forms required to record fluid levels such as Water Level Record (Form SP-11) or site field book.
6. Complete a Vendor Evaluation Form (QSF-012) and file in the Project file for any Vendors that do not have full approval status or not listed on the Approved Vendor List (QSL-004). Completion of a Safety and Health Schedule (QSF-030 for Canadian Work; QSF-031 for U.S. Work) is necessary for all Vendors who complete field services. Prior to mobilization on site, the Vendor must submit the form to the Regional Safety and Health Manager for review and approval (if not already posted on QSL-004).
7. Confirm with the Project Manager and Project Coordinator that a Property Access/Utility Clearance Data Sheet (QSF-019) has been completed. For residential monitoring, ensure that homeowners have been notified of the intended monitoring event. Confirm the presence of any dogs on site, modify the site specific Job Safety Analysis if there is a dog.
8. Arrange access to the site. Obtain all well and site keys. Consider site access and well conditions (e.g., snow, insects, bee hives, wasp nests).
9. For surface water monitoring consider whether hazards exist due to deep/fast moving water, difficult access, and if additional CRA personnel are required for safety and health reasons.

10. For residential sampling, contact homeowners to make arrangements for a site visit, arrange for site dog to be removed from all areas where a CRA employee will be working. The client or other party may be responsible for making arrangements.
11. Determine measurement notification needs with the Project Coordinator. Have the client, regulatory agency, landowner been notified?
12. Evaluate monitoring notification needs with the Project Coordinator. Have the regulatory groups, client, landowner, and CRA personnel been notified of the activities?
13. Plan the sequence of monitoring activities to reduce the potential for cross-contamination. For groundwater monitoring, start with clean wells and progress to impacted wells. For surface water monitoring, start downstream and progress upstream.

8.4 SAFETY AND HEALTH

CRA is committed to conducting field activities in accordance with sound safety and health practices. CRA adheres to high safety standards to protect the safety and health of all employees, subcontractors, customers, and communities in which they work. The safety and health of our employees takes precedence over cost and schedule implications.

Field personnel are required to implement the Safety Means Awareness Responsibility Teamwork (SMART) program as follows:

- Assure the Health and Safety Plan (HASP) is specific to the job and approved by a Regional Safety & Health Manager.
- Confirm that all HASP elements have been implemented for the job.
- A Job Safety Analysis (JSA) for each task has been reviewed, modified for the specific site conditions and communicated to all appropriate site personnel. The JSAs are a component of the HASP.
- Incorporate Stop Work Authority; Stop, Think, Act, Review (STAR) process; Safe Task Evaluation Process (STEP); Observations process; Near Loss and Incident Management process in the day-to-day operations of the job.
- Review and implement applicable sections of the CRA Safety & Health Policy Manual.
- Confirm that all site personnel have the required training and medical surveillance , as defined in the HASP.
- Be prepared for emergency situations, locating safety showers, fire protection equipment, evacuation route, rally point, and first aid equipment before you begin working, and make sure that the equipment is in good working order.
- Maintain all required Personal Protective Equipment (PPE), safety equipment, and instrumentation necessary to perform the work effectively, efficiently and safely.
- Be prepared to call the CRA Incident Hotline at 1-866-529-4886 for all incidents involving injury/illness, property damage, and vehicle incident and/or significant Near Loss.

It is the responsibility of the Project Manager to:

- Ensure that all CRA field personnel have received the appropriate health and safety and field training and are qualified to complete the work.
- Provide subcontractors with a Job Hazard Analysis to enable them to develop their own HASP.
- Ensure that all subcontractors meet CRA's (and the Client's) safety requirements.

8.5 QUALITY ASSURANCE/QUALITY CONTROL

A well-designed QA/QC program will:

- ensure that data of sufficient quality are obtained, for proper site management decisions or remediation design;
- allow for monitoring of staff and contractor performance; and
- verify the quality of the data for the regulatory agency.

It is important to note that a QA/QC program should be developed on a site-specific basis. QA/QC requirements are discussed in Section 3.9.

8.6 EQUIPMENT DECONTAMINATION

Equipment decontamination procedures for a fluid level monitoring program will typically be described in detail in the site-specific Work Plan or in the QAPP.

Equipment is decontaminated between monitoring locations and prior to leaving the site. Upon completion of the monitoring program, all equipment is decontaminated at the site and then returned clean to the appropriate field equipment manager.

For most groundwater, residential, and surface water fluid level monitoring programs, monitoring equipment (e.g., water level indicators, oil/water interface probes, weighted tapes) is typically cleaned as follows:

1. Wash with clean potable water and laboratory detergent.
2. Rinse with tap water.
3. Rinse with deionized water.
4. Air dry for as long as possible.

If required, the following steps may be added under specific monitoring programs when certain chemical compounds are present within the monitored media:

1. Rinse with 10 percent nitric acid (only if samples are to be analyzed for metals).
2. Rinse with deionized water.
3. Rinse with appropriate solvent (pesticide grade isopropanol, methanol, acetone, hexane, if required).
4. Rinse again with deionized water.

Monitoring fluid levels in residential wells also may require the following additional steps:

1. Rinse with tap water.
2. Rinse with a 10 percent or stronger bleach solution before and after fluid level monitoring in each well.
3. Rinse with distilled water.

Caution:	*Check the QAPP to confirm the cleaning protocol. Use of incorrect cleaning protocol could invalidate chemical data.*

8.6.1 DECONTAMINATION FLUID DISPOSAL

Project-specific disposal methods for decontamination fluids are determined by the Project Manager during the monitoring program's planning and preparation stage (see Section 8.3), but may include:

1. Off-site treatment at private treatment/disposal facility or publicly owned treatment facilities (sanitary sewer).
2. On-site treatment at a client-operated facility.
3. Direct discharge to the surrounding ground surface, allowing infiltration to the underlying subsurface.
4. Direct discharge to an impervious pavement surface allowing for evaporation.

Options 3 and 4 are permitted only after careful review of these practices and the anticipated site conditions. Under no circumstances shall CRA personnel aggravate an existing condition or spread contamination into clean areas.

Decontamination fluids (specifically cleaning solvents/acids) are segregated and collected separately from wash water and purge water. Often, small volumes of solvents used during the course of a groundwater, residential, or surface water monitoring program will evaporate if left in an open pail. If evaporation is not possible, off-site disposal needs to be arranged.

8.7 FIELD PROCEDURES FOR GROUNDWATER/RESIDENTIAL/ LEACHATE FLUID LEVEL MONITORING

Fluid level monitoring in monitoring wells, residential wells, and leachate wells is very similar. The typical series of events that takes place for a fluid level monitoring program is:

1. Well/monitoring location identification and inspection.
2. Air monitoring.
3. Water level monitoring.
4. Well depth sounding.
5. Equipment decontamination.
6. Field note completion and review.
7. Sample record documentation, equipment return.
8. Completion and distribution of appropriate forms.

8.7.1 WELL IDENTIFICATION AND INSPECTION

At sites with numerous wells or wells nests, misidentification of wells can easily occur. The CRA representative must be alert to the possibility of potential cap switching, mislabeled wells, or unlabeled well locations.

Determine proper well location and identification by comparing the well log details to the measured well depths (i.e., total well depth, casing diameter, casing stick-up, or stick-down distances), field tie-ins, and site plan.

Once well identification has been established, perform a thorough well inspection:

1. Determine if the well cap and lock are secure, and check for vandalism.
2. If no lock is present, dedicate a new lock to the well location.
3. Examine the integrity of the surface seal.
4. Check for cracks, evidence of frost heave, or subsidence in the vicinity of the well.
5. Examine the integrity of the protective casing. Ensure that the casing can be closed and locked.
6. If required, re-label the well to assist in future identification.
7. Record all the well inspection details in the field book to document well conditions and suitability for groundwater sampling activities.
8. Forward the well inspection results to the Project Coordinator. If well repairs are required this must be done immediately.

8.7.2 AIR MONITORING

Prior to removing a well cap, measure the breathing space above the well with a photoionization detector (PID) to establish background undifferentiated organic vapor levels. Repeat this process once the well cap has been removed. If either of the PID levels exceed the air quality criteria established in the HASP, air-purifying respiratory (APR) protection or a supplied air system is required. Also take a PID reading inside the riser pipe. It should be noted that high levels of contaminants may harm certain air monitoring equipment. This PID reading is a good indication of elevated chemical or non-aqueous phase liquids (NAPL) presence. Report all elevated PID levels to the Project Coordinator immediately to determine if additional health and safety and Personal Protective Equipment (PPE) is required. The HASP will provide the required action levels and PPE.

Note: This may not be required at all sites. Confirm with the Project Coordinator.

8.7.3 REFERENCE POINT

Fluid level measurements are made relative to a surveyed reference point. For groundwater level measurements, the reference point is usually the top of the well riser or casing. (The protective casing should not be used as a reference point.) The top of the well riser/casing is usually not level and/or square; therefore, the reference point must be clearly marked on the riser and noted in the field book. Clearly marking the reference point will eliminate future measurement errors. Measure and record the distance from the reference point to the ground surface. The elevation of the reference point should be determined to the nearest 0.01 foot (1 mm). Typically, the reference point is the highest point on non-level riser pipes.

8.7.4 WATER LEVEL MONITORING/WELL DEPTH SOUNDING

Prior to commencing well purging and groundwater sampling, the water level is measured for hydraulic monitoring and to determine the well volume. Typically, a complete round of water level measurements is taken at a site to establish groundwater conditions prior to initiating well purging or groundwater sampling activities.

A watertight cap provides an airtight seal on the casing and the water level positioned in the casing area. These caps are most commonly used on flush mount monitoring wells. The cap creates a vacuum or pressurized condition in the casing section which can support or depress the water column in the well casing. This can produce an artificially high or low water level in the well casing. This effect can cause a few inches or feet of error in the static water level. Once the watertight cap is removed, allow the pressure to stabilize for approximately half an hour. Measure the water level frequently to ensure that stabilization of the water level has occurred. Once the water level has stabilized (i.e., is static) the correct water level may be measured. If unsure of whether the water level has stabilized, note this in the field book/water level record form.

A number of instruments are available to measure groundwater levels. CRA typically uses:

- battery-operated water level indicator (i.e., audible and/or visual identification of water level);
- battery-operated oil/water interface probe [i.e., audible and/or visual identification of water level and presence of non-aqueous phase liquid (NAPL)]; and
- electronic transducer (numerous manufacturers) and recording device for long-term hydraulic monitoring.

This section describes in detail the equipment and monitoring techniques for water level measurements.

Well depth sounding is often required to confirm well identification, evaluate the accumulation of sediment in the well bottom, or assist in determining the standing well volume. Sounding is performed using a water level indicator or a measuring tape with a weighted end (plopper). The water level indicator or weighted tape is lowered to the bottom of the well and a comparison is made of the installed well depth versus the measured well depth. The presence of excessive sediment or drill cuttings may warrant redevelopment of the well prior to well purging and groundwater sampling activities.

The total well depth is compared to the original installed total well depth. If the well screen is more than 50 percent blocked by accumulated sediment, the well should be redeveloped prior to the next groundwater sampling event. Report all wells requiring redevelopment to the Project Coordinator. Well depth sounding is performed on an annual or biannual basis if the well is equipped with a dedicated pump.

For low-flow purging (LFP), well depth measurement is performed to ensure proper pump intake placement. The use of a wide-based probe, such as a weighted tape, is necessary to minimize penetration and disturbance of accumulated sediment. The measuring device is lowered slowly through the water column to the well bottom to minimize mixing of the stagnant well casing water and disturbance of sediment.

Note:	*If well sounding is performed, the entire measuring device must be thoroughly decontaminated prior to re-use. Measuring the well depth with certain water level indicators may damage the probe seal. Therefore, a tape with a weighted end should be used to measure well depth. Make sure to add in the length of the weight below the end of the tape, if used.*

The following subsections describe the most common techniques used by CRA to measure fluid levels.

8.7.4.1 <u>ELECTRICAL WATER LEVEL INDICATORS</u>

The most common method of obtaining water level measurements is the electronic water level indicator (e.g., Solinst). These meters consist of calibrated cable or tape with a weighted sensing tip at the end.

When the tip contacts the water, an electric circuit is completed and the light and/or buzzer signals the contact. The following procedures shall be used with electrical water level meters:

1. Check the proper operation of the meter by inserting the tip into water and noting if the contact is registered clearly (on some meters, the sensor is in the midpoint of the metal tips). Deionized water cannot be used for this check, as it will not conduct an electrical current. Always check to see if the tape has been previously repaired and if a correction of the measurement is required.
2. Dry the tip and then slowly lower the tip into the well until contact with the water is indicated.
3. Slowly raise the tip until the light and/or buzzer just begins to deactivate. This indicates the static water level.
4. Using the thumb and index finger, grasp the tape at the reference point and note the reading to the nearest 0.01 foot (1 mm).
5. The reading should be checked twice more before removing the tape from the well. This helps confirm that the water level is static.
6. Record the water level measurement in the field book and/or water level form. Compare to previous measurements to see if significant changes [i.e., greater than 2 feet (0.6 m)] have occurred. Recheck the water level if a significant difference is measured.
7. Decontaminate the submerged end of the tape in accordance with the Work Plan.

Note: In cases where water levels will be measured on several occasions, it may be advantageous to set up a separate page within the field book for the water level measurements from each well. This will allow the measurements to be compared to the previous water level events and allow significant differences to be easily identified.

8.7.4.2 TAPE/PLOPPER

A weighted standard surveying tape, typically graduated in increments of 0.01 foot (1 mm) weighted with a sounding device, was for many years the only means used for measuring fluid levels in monitoring wells, boreholes, and pits. It should still be considered as a failsafe backup method (there are no batteries or electrical circuits to fail), or alternative device if an electrical level indicator is not available.

Although the tape can be weighted with any heavy object (e.g., a nut, fishing sinker), the device commonly used by CRA is a hollow-pipe section described as a "plopper". The exact top of the fluid level can be determined by carefully listening for the sound the plopper makes when it contacts the fluid surface. The plopper is hung from the bottom of the tape such that the capped end is up and the open end is down. When the open end of the hollow pipe touches the fluid surface, a hollow plopping sound results. By moving the tape up and down ever so slightly, the fluid level can be determined very precisely.

Since the weight is hanging from the "zero" end of the tape, and since it is the weight touching the fluid level which allows detection of the fluid surface, the length of the weight must be added to the tape reading. It is most convenient (and results in fewer errors) if the weight is purposely designed to be a standard, easily remembered length, say 0.5 foot (15 cm). Thorough field cleaning the hollow "water plopper" is very important due to its shape and the potential for contaminants lingering around the internal area.

8.7.4.3 INTERFACE PROBE

Electrical water level indicators are not reliable when light non-aqueous phase liquids (LNAPL) are floating on the water surface, therefore another method to determine fluid levels is required.

Phase-separated liquids may consist of lighter-than-water materials (i.e., petroleum hydrocarbons) which float on the groundwater surface are categorically referred to as LNAPL; or heavier-than-water materials (dense organic chemicals) which are denser than water and will sink until a confining layer or less permeable layer is encountered, and are categorically referred to as dense non-aqueous phase liquids (DNAPL). Interface probes will detect the surface of LNAPL layers and the interface between LNAPL and groundwater or groundwater and DNAPL. Some oil/water interface probes may not detect DNAPL.

The interface probe uses an optical liquid sensor in conjunction with an electric circuit to detect the top of a phase-separated liquid and the interface between the phase layer and water (water level). The procedure for use of this probe is:

1. Lower the probe tip into the well until discontinuous beeping is heard. This indicates the top of the oil has been detected. Grasp the calibrated tape at the reference point and note the reading. Confirm the reading by slowly raising and lowering the probe to the level of the phase layer.
2. Once the top of the phase layer is confirmed, slowly lower the probe until a continuous sound is heard. This indicates that the water level has been encountered. Grasp the tape at the reference point and note the reading. Confirm this water level measurement.
3. Decontaminate the submerged end of the tape and probe prior to the next use in accordance with the Work Plan.

8.7.4.4 ALTERNATIVE NAPL MEASUREMENT METHODS

Alternative NAPL measurement methods exist in the event an interface probe is unavailable or not functioning properly. These methods tend to be less accurate than the interface probe but may be used to establish an estimated NAPL measurement.

Clear Bailer – A clear bottom-loading bailer may be used to estimate NAPL thickness if floating or denser than water. If NAPL presence is suspected, the bailer is carefully lowered to the location of suspected NAPL presence (top of water column/base of water column), and slowly removed and examined for NAPL. If present, the column of NAPL within the clear bailer can be measured to estimate the NAPL thickness within the groundwater column.

Weighted Cord – Primarily used for DNAPL measurements, a weighted "cotton" string or cord may be lowered to the base of the well and inspected upon retrieval. Typically, the lower DNAPL layer will "coat" the string indicating the approximate thickness of this layer. This method, if effective at a site, can be an economical and quick means of measuring DNAPL layers.

Clear bailers and weighted cords are considered disposable and thus are not reused, resulting in no requirement for decontamination.

LNAPL Thickness/Displacement Correction

Historical studies and direct field observations have shown that there is no direct relationship between the thickness of LNAPL measured in a well and the thickness of LNAPL in the soil adjacent to the well. No quantitative relationship exists other than a general observation has been found that the more porous the soil, the more the NAPL thickness in the well seems to reflect the thickness in the soil.

The occurrence of LNAPL in a well is a positive indication that LNAPL is present in the subsurface in volumes exceeding that which is adsorbed by the soil. The repeated occurrence of LNAPL upon bailing is a positive indication that those adsorption volumes are still exceeded in the soil; a trend of decreasing LNAPL thickness with repeated bailing suggests that the volume is being reduced to the adsorption level. The occurrence of phase-separated material in a well indicates nothing more quantitative than these general relationships.

When compiling a groundwater contour plan or utilizing groundwater data for other compilations, it is necessary to calculate the elevation of the groundwater by eliminating the effects of the LNAPL layer. The displacement correction for an LNAPL layer is as follows:

(Measured elevation of groundwater surface) + (measured LNAPL thickness times the LNAPL specific gravity) = corrected groundwater elevation.

Generally, a specific gravity of 0.75 is a good average value for LNAPL layer displacement corrections. If more specific knowledge of the LNAPL is available, a site- or well-specific gravity can be used.

8.7.4.5 PRESSURE TRANSDUCER AND RECORDER

Pressure transducers and recorders are commonly used for short- and long-term monitoring programs, pumping tests, and single well response tests. Pressure transducers contain a pressure sensitive sensor which measures the pressure effects of water and atmospheric air above the sensor. The pressure reading is then recorded on the transducers logger at the required interval selected by the user.

There are several brands of pressure transducers available for use and most of which convert the pressure data to a corresponding head of water above the installed depth of the sensor using a simple calculation. To convert accurately to groundwater elevations, several depth to water readings are required. Not all pressure transducers correct for atmospheric pressure, therefore the barometric pressure must be subtracted from the pressure readings. This is particularly important for data collection during long-term monitoring programs, as the changes in barometric pressure can have a substantial effect on the data being collected by the pressure transducer. Barometric pressure can be corrected by gathering barometric pressure data using a pressure transducer specifically designated for this task, then subtracting the barometric pressure data from the water level pressure data. As an alternative, barometric pressure data can be obtained from local weather stations and the effects of the barometric pressure can be compensated for using a simple calculation. Used properly, a pressure transducer is a valuable tool when completing single well response tests, specifically when the hydraulic conductivity of the formation is too fast to monitor changes manually.

8.8 FIELD PROCEDURES FOR SURFACE WATER FLUID LEVEL MONITORING

Fluid level monitoring at surface water level locations is generally completed in the same manner as other fluid level monitoring methods. The typical series of events that takes place for a surface water level monitoring program is:

1. Surface water location identification and inspection.
2. Water level monitoring.
3. Flow measurements.
4. Equipment decontamination.
5. Field note completion and review.
6. Sample record documentation, equipment return.
7. Completion and distribution of appropriate forms.

8.8.1 SURFACE WATER LOCATION IDENTIFICATION AND INSPECTION

At sites with numerous surface water monitoring locations, misidentification of locations has occurred. The CRA representative must be alert to the possibility of potential mislabeled or unlabeled surface water monitoring locations.

Determine proper surface water monitoring location and identification by comparing the physical location of the surface water location to current Site Plan in addition to field tie-ins.

Once the surface water location identification has been established, complete a thorough inspection:

1. Examine the integrity of the staff gauge, or T-bar, and check for vandalism.
2. Inspect for and remove any debris that may have collected around the monitoring location which could potentially impact the reference elevation of the monitoring point.

3. Examine the integrity of the surrounding area to determine safe monitoring conditions.
4. If required, re-label the surface water location to assist in future identification.
5. Record all inspection details in the field book to document the conditions and suitability for surface water sampling.
6. Forward the inspection results to the Project Coordinator. If reinstallation or resurveying is required, this must be done immediately.

8.8.2 REFERENCE POINT

Fluid level measurements are made relative to a surveyed reference point. For surface water level measurements, the location of the reference point can vary depending on the surface water monitoring location (e.g., T-bar, staff gauge, piezometer, concrete structures at bridge abutments, and sewer outfalls.). The reference point must be clearly marked at the monitoring location and noted in the field book. Clearly marking the reference point will eliminate future measurement errors. The elevation of the reference point should be determined to the nearest 0.01 foot (1 mm).

During surface water monitoring, if staff gauges are damaged or missing they should be replaced and then resurveyed to establish horizontal and vertical control.

8.8.3 SURFACE WATER LEVEL MONITORING

Surface water level monitoring is commonly completed in conjunction with sampling programs. Careful attention must be paid to ensuring suspended sediments caused by monitoring activities do not impact the surface water samples. Surface water levels should therefore be collected beginning downstream and progressing upstream.

A number of instruments are available to measure groundwater levels. CRA typically uses:

- battery-operated water level indicator (i.e., audible and/or visual identification of water level);
- battery-operated oil/water interface probe (i.e., audible and/or visual identification of water levels and presence of NAPL); and
- electronic transducer (numerous manufacturers) and recording device for long-term hydraulic monitoring.

The equipment and monitoring techniques for surface water level measurements are similar to groundwater level measurements. Refer to these sections for applicable information.

For staff gauges and T-bars, the depth from the reference point to the water surface is measured. Where practical, the depth to water/sediment interface should also be measured.

8.9 FOLLOW-UP ACTIVITIES

The following should be performed once groundwater, residential, and surface water sampling is completed:

1. Double check the Work Plan and QAPP to ensure all levels have been collected and confirm with the Project Coordinator.
2. Decontaminate all equipment at the site then return it clean to the appropriate field equipment manager.
3. Dispose of cleaning fluid as specified in the Work Plan.
4. Complete and file the appropriate forms, data sheets, and field notes. For groundwater, residential, leachate, and surface water fluid levels, these forms include:
   - Water Level Measurement Equipment and Supply Checklist (Form SP-10);
   - Project Planning, Completion, and Follow-Up Checklist (Form SP-02); and
   - Water Level Record (Form SP-11).
5. Return site and well keys.

8.10 REFERENCES

For additional information pertaining to fluid level monitoring the user of this manual may reference the following:

ASTM 4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)

ASTM D6000 Guide for Presentation of Water-Level Information from Ground-Water Sites

CRA FIELD TRAINING MANUAL

SECTION 7.0:

WATER SAMPLING STANDARD OPERATING PROCEDURES

A. GROUNDWATER
B. RESIDENTIAL
C. SURFACE WATER

(F104)

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7.0 WATER SAMPLING (GROUNDWATER, RESIDENTIAL, AND SURFACE WATER) STANDARD OPERATING PROCEDURES

7.1 INTRODUCTION

Groundwater, residential, and surface water sampling are conducted in order to characterize the groundwater and surface water quality at a site. Standard Operating Procedures (SOPs) are presented herein for the collection of groundwater and surface water samples from:

- Monitoring wells
- Residential wells
- Surface water bodies

This guideline is not intended to provide the basis for designing a groundwater or surface water monitoring program, but instead assumes that a groundwater and/or surface water monitoring program has already been designed. It is also assumed that a site-specific Work Plan has been established and that a CRA representative is preparing to mobilize to the site.

Groundwater and surface water sampling procedures vary from project to project due to:

- Different chemicals of concern
- Different guidance provided by local, provincial/state, and/or federal regulatory agencies with jurisdiction at the site
- The specific objectives of the project

It is essential that all groundwater, residential, and surface water sampling activities conform to local, state/provincial, and federal regulations. Therefore, it is essential that the CRA representative carefully reviews the Work Plan requirements. The primary goal of groundwater, residential, and surface water sampling is the collection of samples representative of the hydrostratigraphic unit and/or surface water body. It is necessary to use appropriate sampling techniques to collect representative samples that provide reliable and reproducible results in accordance with the Work Plan and all relevant regulations.

The remainder of this section is organized as follows:

- Section 7.2 Background
- Section 7.3 Planning and Preparation
- Section 7.4 Safety and Health
- Section 7.5 Quality Assurance/Quality Control
- Section 7.6 Equipment Decontamination
- Section 7.7 Field Procedures for Groundwater Sampling
- Section 7.8 Field Procedures for Residential Sampling

- Section 7.9 Field Procedures for Surface Water Sampling
- Section 7.10 Follow-Up Activities
- Section 7.11 References

7.2 BACKGROUND

The objective of a groundwater and residential monitoring program is to obtain samples that are representative of existing groundwater conditions, or samples that retain the physical and chemical properties of groundwater in the hydrostratigraphic unit. Surface water sampling is performed to collect samples that are representative of physical and chemical properties of surface water bodies. Improper sampling and transport practices will cause compounds of interest to be removed or added to a sample prior to analysis. The importance of proper and consistent field sampling methods cannot be over emphasized. It is equally important that proper documentation occurs throughout the sampling program.

The most important aspect of groundwater sampling is the collection of groundwater samples that are free of suspended silt, sediment, or other fine-grained material. Fine-grained material has a variety of chemical compounds sorbed to the particles or has the ability to sorb chemicals from the aqueous phase. This causes a bias in the subsequent analytical results. Reproducible and reliable analytical data are invaluable to a groundwater monitoring program. CRA frequently criticizes the sampling activities completed by others due to the collection and analyses of turbid samples. This SOP discusses sampling protocols that typically achieve sediment-free samples.

When sampling for monitored natural attenuation (MNA) parameters, more stringent protocols are followed to ensure sediment-free samples that are representative of the total mobile load (i.e., dissolved and naturally suspended particles). Low-flow purging (LFP) techniques are strongly recommended, if not mandated, when collecting groundwater samples for MNA parameters. The LFP techniques detailed in Section 7.7.5.3 are in accordance with United States Environmental Protection Agency (USEPA) LFP procedures (Puls and Barcelona, 1996).

Groundwater sampling is required for various reasons, including:

- Investigating potable or industrial water supplies
- Tracking contaminant plumes
- Investigating a site with suspected groundwater contamination

Groundwater is usually sampled from in-place wells, installed either temporarily or permanently. Municipal, industrial, or residential wells may also be sampled during an investigation. When completing residential well sampling it is important that representative samples are collected. Poor or incorrect sampling techniques will result in erroneous results. Incorrect results disclosed to the public will create a false impression, making it difficult to change the perception when correct results are reported.

Groundwater and residential sample collection are performed from non-impacted to most impacted locations. This eliminates the potential for cross-contamination. A review of all historical analytical data is performed to ensure the exact sampling sequence.

Surface water sampling locations are selected based on many factors including:

- The study objectives
- The location of point source discharges
- The location of no-point source discharges and tributaries
- The presence of structures (e.g., bridges, dams)
- Accessibility

Surface water sampling should be performed from downstream to upstream locations. This ensures that surface water sampling activities do not cause suspended sediments to bias samples collected downstream.

7.3 PLANNING AND PREPARATION

Prior to groundwater, residential, and surface water sampling:

1. Review the Work Plan, project documents, and Site-Specific Health and Safety Plan (HASP) with the Project Manager/Coordinator.
2. Review the Quality Assurance Project Plan (QAPP) with the Project Coordinator and Project Chemist to determine Quality Assurance/Quality Control (QA/QC) and decontamination requirements.
3. Complete a Field Equipment Requisition Form (QSF-014). Assemble all sampling equipment and supplies required per the Groundwater Sampling Equipment and Supply Checklist (Form SP-05). The Project Planning, Completion, and Follow-Up Checklist (Form SP-02) should be used for guidance throughout the project.
4. Assemble the site plan, well logs, and previous sampling/purging data required for the sampling event. Determine the exact number and locations of wells to be sampled.
5. Obtain all forms to record purging and sampling activities (Forms SP-06, SP-07, SP-08, and SP-09).
6. Confirm with the Project Manager/Coordinator that a Property Access/Utility Clearance Data Sheet (QSF-019) has been completed. For residential sampling, ensure that homeowners have been notified of the intended sampling event. Confirm the presence of any dogs on site, modify the site-specific Job Safety Analysis, if there is a dog.

7. Arrange access to the site. Obtain all well and site keys. Consider site access conditions (e.g., snow).

8. For surface water sampling consider if hazards exist due to deep/fast moving water, difficult access, and if additional CRA personnel are required for safety and health reasons.

9. For residential sampling contact homeowners to make arrangements for a site visit, arrange for site dog to be removed from all areas where a CRA employee will be working. The client of another party may be responsible for making arrangements.

10. Complete a Vendor Evaluation Form (QSF-012) and file in the Project file for any Vendors that do not have full approval status or are not listed on the Approved Vendor List (QSL-004). Completion of a Safety and Health Schedule (QSF-030 for Canadian work; QSF-031 for U.S. work) is necessary for all Vendors who complete field services. Prior to mobilization on site, the Vendor must submit the form to the Regional Safety and Health Manager for review and approval (if not already posted on QSL-004).

11. Contact the CRA Chemistry group to arrange:
    - SSOW (Simplified Scope of Work)
    - Laboratory
    - Sample containers delivery
    - Preservatives if required
    - Filtration information if required
    - Coolers
    - Shipping details
    - Sample starting date
    - Expected duration of sampling program

12. If several sampling events are planned, evaluate with the client the benefit of purchasing and installing dedicated sampling equipment. Dedicated purging and sampling equipment reduces potential cross-contamination and reduces decontamination requirements. At a minimum, sample tubing is dedicated to each well and is left secured in the well for future use. For LFP it is recommended that each well is dedicated with a bladder pump and tubing to eliminate well disturbance.

13. Evaluate sample notification needs with the Project Coordinator. Have the regulatory groups, client, landowner, CRA personnel, and laboratory been notified of the sampling activities?

14. Evaluate containment and disposal requirements for purge waters.

15. Plan sampling activities to ensure that wells that historically go dry or have poor recharge fit into the sampling program. This will reduce the time required for sample collection.

16. Plan the sequence of sampling activities to reduce the potential for cross-contamination. For groundwater sampling, start with clean wells and progress to impacted wells. For surface water sampling, start downstream and progress upstream.

7.4 SAFETY AND HEALTH

CRA is committed to conducting field activities in accordance with sound safety and health practices. CRA adheres to high safety standards to protect the safety and health of all employees, subcontractors, customers, and communities in which they work. The safety and health of our employees takes precedence over cost and schedule implications.

Field personnel are required to implement the Safety Means Responsibility Awareness Teamwork (SMART) program as follows:

- Assure the HASP is specific to the job and approved by a Regional Safety & Health Manager.
- Confirm that all HASP elements have been implemented for the job.
- A Job Safety Analysis (JSA) for each task has been reviewed, modified for the specific site conditions, and communicated to all appropriate site personnel. The JSAs are a component of the HASP.
- Incorporate Stop Work Authority; Stop, Think, Act, Review (STAR) process; Safe Task Evaluation Process (STEP); Observations process; Near Loss and Incident Management process in the day-to-day operations of the job.
- Review and implement applicable sections of the CRA Safety & Health Policy Manual.
- Confirm that all site personnel have the required training and medical surveillance as defined in the HASP.
- Be prepared for emergency situations, locating safety showers, fire protection equipment, evacuation route, rally point, and first aid equipment before you begin working, and make sure that the equipment is in good working order.
- Maintain all required Personal Protective Equipment (PPE), safety equipment, and instrumentation necessary to perform the work effectively, efficiently, and safely.
- Be prepared to call the CRA Incident Hotline at 1-866-529-4886 for all involving injury/illness, property damage, vehicle incident, and/or significant Near Loss.

It is the responsibility of the Project Manager to:

- Ensure that all CRA field personnel have received the appropriate health and safety and field training and are qualified to complete the work
- Provide subcontractors with a Job Hazard Analysis to enable them to develop their own HASP
- Ensure that all subcontractors meet CRA's (and the Client's) safety requirements

7.5 QUALITY ASSURANCE/QUALITY CONTROL

A well-designed QA/QC program will:

- Ensure that data of sufficient quality are obtained, for proper site management decisions or remediation design
- Allow for monitoring of staff and contractor performance
- Verify the quality of the data for the regulatory agency

It is important to note that a QA/QC program should be developed on a site-specific basis. QA/QC requirements are discussed in Section 3.9.

7.6 EQUIPMENT DECONTAMINATION

Equipment decontamination procedures for a groundwater, residential, or surface water monitoring program will be described in detail in the site-specific Work Plan or in the QAPP.

Equipment is decontaminated between sampling locations and prior to leaving the site. Upon completion of the sampling program, all equipment is decontaminated at the site and then returned clean to the appropriate field equipment manager.

For most groundwater, residential, and surface water sampling programs, sampling equipment (e.g., pumps, bailers, water level indicators) is typically cleaned as follows:

1. Wash with clean potable water and laboratory detergent, using a brush as necessary to remove particulates.
2. Rinse with tap water.
3. Rinse with deionized water.
4. Air dry for as long as possible.

If required, the following steps may be added when sampling for Volatile Organic Compounds (VOCs) and metals:

1. Rinse with 10 percent nitric acid (only if samples are to be analyzed for metals).
2. Rinse with deionized water.
3. Rinse with appropriate solvent (pesticide grade isopropanol, methanol, acetone, hexane, if required).
4. Rinse again with deionized water.
5. Air dry for as long as possible.

6. Wrap samplers in aluminum foil to prevent contamination.

Caution:	*Check the QAPP to confirm the cleaning protocol. Use of incorrect cleaning protocol could invalidate chemical data.*

7.6.1 PURGE WATER AND DECONTAMINATION FLUID DISPOSAL

Project-specific disposal methods for purged groundwater and decontamination fluids are determined by the Project Manager during the sampling program's planning and preparation stage (see Section 7.3), but may include:

1. Off-site treatment at private treatment/disposal facility or publicly owned treatment facilities (sanitary sewer)
2. On-site treatment at a client-operated facility
3. Direct discharge to the surrounding ground surface, allowing infiltration to the underlying subsurface
4. Direct discharge to an impervious pavement surface allowing for evaporation

Options 3 and 4 are permitted only after careful review of these practices and the anticipated site conditions. Under no circumstances shall CRA personnel aggravate an existing condition or spread contamination into clean areas.

Decontamination fluids (specifically cleaning solvents/acids) are segregated and collected separately from wash water and purge water. Often small volumes of solvents used during the course of a groundwater, residential, or surface water sampling program will evaporate if left in an open pail. If evaporation is not possible, off-site disposal need to be arranged.

7.7 FIELD PROCEDURES FOR GROUNDWATER SAMPLING

The typical series of events that takes place for a groundwater sampling program is:

1. Well identification and inspection
2. Air monitoring
3. Water level monitoring
4. Well depth sounding
5. Well volume calculation
6. Purging and sampling equipment installation
7. Well purging and stabilization monitoring
8. Sample collection, sample preparation, completion of chain-of-custody, (COC) sample packaging

9. Final water level monitoring (if required), purging, sampling equipment removal, secure the well
10. Equipment decontamination
11. Field note completion and review
12. Sample shipment and COC distribution
13. Purged groundwater and decontamination fluid disposal
14. Sample record documentation, equipment return
15. Completion and distribution of appropriate forms

It is recommended that new plastic sheeting be placed on the ground around the well to prevent contamination of purging and sampling equipment and accessories (e.g., pumps, hoses, rope.).

7.7.1 WELL IDENTIFICATION AND INSPECTION

At sites with numerous wells or wells nests, misidentification of wells has occurred. The CRA representative must be alert to the possibility of potential cap switching, mislabeled wells, or unlabeled well locations.

Determine proper well location and identification by comparing the well log details to the measured well depths (i.e., total well depth, casing diameter, casing stick-up, or stick-down distances), field tie-ins, and site plan.

Once well identification has been established, complete a thorough well inspection:

1. Determine if the well cap and lock are secure, and check for vandalism
2. If no lock is present, dedicate a new lock to the well location
3. Examine the integrity of the surface seal
4. Check for cracks, evidence of frost heave, or subsidence in the vicinity of the well
5. Examine the integrity of the protective casing. Ensure that the casing can be closed and locked
6. If required, re-label the well to assist in future identification
7. If the well is installed with dedicated sampling equipment, check for cracks or leaks in tubing, and worn or frayed rope
8. Record all the well inspection details in the field book to document well conditions and suitability for groundwater sampling activities
9. Forward the well inspection results to the Project Coordinator, especially if repairs are required

7.7.2 AIR MONITORING

Prior to removing a well cap, measure the breathing space above the well with a photoionization detector (PID) to establish background of undifferentiated organic vapor levels. Repeat this process once the well cap has been removed. If either of the PID levels exceed the air quality criteria established in the HASP, air-purifying respiratory (APR) protection or a supplied air system is required. Also take a PID reading inside the riser pipe. This PID reading is a good indication of elevated chemical or non-aqueous phase liquids (NAPL) presence. Report all elevated PID levels to the Project Coordinator immediately to determine if additional health and safety and personnel protective equipment is required. The HASP will provide the required action levels and PPE.

7.7.3 WATER LEVEL MONITORING/WELL DEPTH SOUNDING

Prior to commencing well purging and groundwater sampling, the water level is measured for hydraulic monitoring and to determine the well volume. Typically, a complete round of water level measurements is taken at a site to establish groundwater conditions prior to initiating well purging or groundwater sampling activities.

A watertight cap provides an airtight seal on the casing and the water level positioned in the casing area. The cap creates a vacuum or pressurized condition in the casing section which can support or depress the water column in the well casing. This can produce an artificially high or low water level in the well casing. This effect can cause a few inches or feet of error in the static water level. Once the cap is removed, allow the pressure to stabilize for about a half hour. Measure the water level frequently to ensure that stabilization of the water level has occurred. Once the water level has stabilized (i.e., is static) the correct water level may be measured.

A number of instruments are available to measure groundwater levels. CRA typically uses:

- Battery-operated water level indicators (i.e., audible and/or visual identification of water level)
- Battery-operated oil/water interface probes (i.e., audible and/or visual identification of water levels and presence of NAPL)
- Electronic transducers (numerous manufacturers) and recording devices for long-term hydraulic monitoring
- Stevens™ recorders (both float and electronic instrumentation) for long-term hydraulic monitoring

Section 8.0 describes in detail the equipment and monitoring techniques for water level measurements.

Well depth sounding is often required to confirm well identification, evaluate the accumulation of sediment in the well bottom, or assist in determining the standing well volume. Sounding is performed using a water level indicator or a measuring tape with a weighted end. The water level indicator or weighted tape is lowered to the bottom of the well and a comparison is made of the installed well depth versus the measured well depth. The presence of excessive sediment or drill cuttings may warrant redevelopment of the well prior to well purging and groundwater sampling activities.

The total well depth is compared to the original installed total well depth. If the well screen is more than 50 percent blocked by accumulated sediment, the well is redeveloped prior to the next groundwater sampling event. Report all wells requiring redevelopment to the Project Coordinator. Well depth sounding is performed on an annual or biannual basis if the well is equipped with a dedicated pump.

For LFP, well depth measurement is performed to ensure proper pump intake placement. The used of a wide-based probe, such as a weighted tape, is necessary to minimize penetration and disturbance of accumulated sediment. The measuring device is lowered slowly through the water column to the well bottom to minimize mixing of the stagnant well casing water and disturbance of sediment.

Note: *Don't forget that decontamination procedures apply to the water level monitoring equipment as well as the groundwater sampling equipment. If well sounding is performed, the entire measuring device must be thoroughly decontaminated prior to re-use. Measuring the well depth with certain water level indicators may damage the probe seal. Therefore, a tape with a weighted end should be used to measure well depth.*

7.7.4 WELL VOLUME CALCULATION

Prior to commencing well purging, the volume of water in the well must be known to determine the volume of groundwater to be removed. A well volume is defined as the volume of water contained in the well screen and casing (and in the case of an open bedrock hole, the volume of water in the open corehole and possibly in the well casing). To determine the standing water volume in a well:

1. Calculate the distance from the bottom of the well to the static water level.
2. Measure the inside diameter of the well or casing. Obtain the volume of standing water in the well using the following formula:

$$V = \pi r^2 h \text{ (7.48 U.S gallons/cubic feet) (1 liter/1,000 cubic centimeters)}$$

where:

V = volume of water in gallons or liters
π = 3.142
r = radius of well casing (feet or meters)
h = depth of water column in the well (feet or meters)

Typical 1-Foot Casing Volumes	
Diameter (inches)	***Gallons (U.S.) of Water Per Foot of Casing***
1.5	0.09
2	0.16
3	0.37
4	0.65
6	1.47

Typical 1 Meter Casing Volumes		
Diameter		***Litres per Meter of Casing***
(inches)	***(cm)***	
1.5	3	1.14
2	5	2.02
3	8	4.56
4	10	8.11
6	15	18.24

7.7.5 WELL PURGING AND STABILIZATION MONITORING

7.7.5.1 TYPICAL METHOD

Prior to initiating groundwater sample collection, the wells is purged of the standing stagnant groundwater volume. This volume is not representative of the groundwater in the hydrostratigraphic unit. Purging is performed until the water in the well is representative of the actual conditions in the hydrostratigraphic unit. Stabilization is usually achieved by the removal of three to five times the volume of standing water in the well (USEPA convention). Purging is considered complete once purged groundwater is free of sediment and field parameters including specific conductance, temperature, and turbidity are stable. Stabilization is achieved when field measurements for specific conductance and temperature are within a range of plus or minus 10 percent of the average for the last three readings. Field measurement for pH should be within a range of plus or minus 0.1 pH unit of the average for the last three readings, and groundwater turbidity values should be less than 5 nephelometric turbidity units (NTU) (guidance value only). Once the number of well volumes required to achieve stabilization is established, the volume required to reach stabilization for future sampling events is reduced or eliminated. Extended purging of a well will generally result in achieving sediment-free groundwater conditions.

During purging, if stabilization has not occurred after removal of five well volumes, purging is continued until ten well volumes have been removed. If stabilization still has not been achieved, stabilization may be dropped as a pre-condition to groundwater sampling. The Project Coordinator should be notified that stabilization has not occurred after the removal of ten well volumes.

At high yielding wells, removing three to five well volumes is usually sufficient prior to initiating groundwater sampling. For low yield wells (i.e., wells that pump dry after one well volume) it is necessary to purge the well dry on three successive days, unless the well recovers to full static conditions in a shorter time. If the recharge is relatively high, groundwater sampling will be initiated once the well has fully recovered to static groundwater conditions, or to a level that is sufficient to collect the necessary groundwater sample volume.

Note: Purging of dry wells should be scheduled to begin on Monday or Tuesday, to reduce weekend requirements.

Turbidity of purged groundwater is evaluated by a visual examination for sediment/silt presence or by using a nephelometer which physically measures groundwater turbidity in NTUs. Generally, a turbidity value of 50 NTU or less is acceptable, although some regulatory agencies have established lower criteria (i.e., less than 5 NTU). If 50 NTU is not achieved, filtration of samples may be required. LFP can generally result in turbidity values less than 5 NTU.

Note: Agitation of the water column within the well will increase turbidity. Therefore, bailers and inertia pumps (Waterra™) are of limited use for collecting sediment-free samples. The tubing of peristaltic pumps must be secured to prevent movement of the tubing within the water column which would disturb sediment. The best method to reduce sediment disturbance is low-volume non-agitation pumping (i.e., bladder pump).

Well purging is accomplished using dedicated equipment or by using either peristaltic, bladder, or other approved purging methods. Purging and sampling equipment are dependent on the total well depth. Bailing can be used for well purging but this method stirs up sediment and increases the purging effort required before stabilization is achieved. Equipment available for well purging is discussed in Section 7.7.7. Monitoring equipment used during well purging includes a water level indicator, pH meter, thermometer, conductivity meter, and turbidity meter.

7.7.5.2 PURGING ENTIRE WATER COLUMN

The purging equipment is lowered into the top of the standing water column. Well purging is completed from as close to the top of the water column as possible, not from the well bottom, unless poor well recovery occurs. Purging from the top of the water column moves water from the formation through the well screen of the well and into the well casing. This allows for the entire static volume to be removed. Purging at depth in the water column does not remove water above the pump intake and results in the collection of unrepresentative samples.

If required, the pump intake can be adjusted. If the recovery rate is greater than the pumping rate, the pump should remain suspended until the required purged volume has been removed. If the recovery rate is less than the pumping rate, the pump should be lowered to ensure the removal of the required well volume.

7.7.5.3 LOW-FLOW PURGING (LFP) TECHNIQUE

LFP purging results in minimal drawdown during well purging, so less purging is required before formation water is removed. The volume required for purging using LFP is significantly reduced. LFP results in less agitation and mobilization of sediments compared to traditional sampling techniques.

A pre-cleaned stainless steel bladder pump equipped with a Teflon™ bladder is strongly recommended for LFP. The discharge line should be polyethylene or Teflon™ lined tubing with an inside diameter of 1/4 or 3/8 inch (6 or 10 mm). Check the Work Plan or QAPP to ascertain the proper bladder and discharge tubing. Smaller discharge tubing ensures that the tubing remains filled with water and reduces air bubbles at low purging rates. The airline to the pump is generally 1/4-inch (6 mm) inside diameter polyethylene tubing. The pump is secured to nylon rope and positioned in the well so that the pump intake is set at the mid-point of the well screen, or a minimum of 2 feet (0.6 m) above the bottom of the well or accumulated sediment level. It is important that the rope, airline, and discharge tubing are measured prior to installation in the well. The bladder pump and tubing are lowered very slowly through the water column to minimize mixing of the stagnant well casing water and to minimize the agitation of sediment into suspension, which would increase the purging time. It is recommended, and in some instances regulated, that pump installation occurs at least 24 hours prior to initiating LFP. It is recommend that a bladder pump be dedicated to the well for regular monitoring events.

During LFP, the pumping rate should be between 100 and 500 milliliters per minute (mL/min). It is recommended that initial pumping be conducted at a lower rate to limit drawdown in the well. During purging, groundwater levels are measured to maintain a maximum 0.4 foot (0.1 m) of drawdown. The pumping rate can be gradually increased during LFP. Pumping rate increases will be dependent on the drawdown and the stabilization of field parameters discussed below. Pumping rate adjustments should occur in the first 15 minutes of purging. After this time the pumping rate should remain constant and flow rate adjustments should be avoided. During purging, the pumping rate and groundwater level should be measured at least every 10 minutes. It is recommended that water level measurements occur at 5-minute intervals.

During LFP, stabilization of the purged groundwater is required to ensure the collection of representative groundwater samples from the formation and not from the stagnant water in the well casing. Field parameters including pH, temperature, specific conductance, oxidation-reduction potential (ORP), dissolved oxygen (DO), and turbidity should monitored during LFP. The measurement of these field parameters is used to evaluate if stabilization of the purged groundwater has occurred prior to the collection of groundwater samples. The field measurements should be measured and recorded at 5-minute intervals. Groundwater stabilization is considered achieved when three consecutive readings for each of the field parameters, taken at 5-minute intervals, are within the following limits:

- pH ±0.1 pH units of the average value of the three readings
- temperature ±3 percent of the average value of the three readings

- conductivity ±0.005 milliSiemen per centimeter (mS/cm) of the average value of the three readings for conductivity <1 mS/cm and ±0.01 mS/cm of the average value of the three readings for conductivity >1 mS/cm
- ORP ±10 millivolts (mV) of the average value of the three readings
- DO ±10 percent of the average value of the three readings
- turbidity ±10 percent of the average value of the three readings, or a final value of less than 5 NTU

During LFP, field parameters are measured using a flow-through cell apparatus. At the start of LFP the purge water is visually inspected for clarity prior to connecting to the flow-through cell. If the purge water is turbid, LFP continues until the purge water is visually less turbid prior to connecting to the flow-through cell. Field parameters may be obtained using individual meters or a multiple meter unit; however, the use of a flow-through cell is highly recommended. All meters must be calibrated daily in accordance with the manufacturer's and CRA's calibration instructions, and a calibration record maintained in a standard CRA field book.

During LFP the meter readings are monitored for evidence of meter malfunction. The following are common indicators of meter malfunctions:

- DO above solubility (e.g., oxygen solubility is approximately 11 milligrams per liter (mg/L) at 10°C) may indicate a DO meter malfunction
- negative ORP and DO less than 1 to 2 mg/L may indicate either an ORP or a DO meter malfunction (i.e., should have positive ORP and DO less than 1 to 2 mg/L under oxidizing conditions)
- positive ORP and DO less than 1 mg/L may indicate either an ORP or a DO meter malfunction (i.e., should have a negative ORP and DO less than 1 mg/L under reducing conditions)

Meter calibration fluids should be available for meter recalibration in the field. Spare meters should also be available for meter replacement if necessary.

Note: DO levels exceeding the solubility of oxygen in water are erroneous and are indicative of meter malfunction or poor sampling techniques causing turbulence and aeration. DO concentrations cannot exceed:
9 mg/L at 20°C 10 mg/L at 15°C 11 mg/L at 10°C 14 mg/L at 1°C

Stabilization will be considered complete when the field parameters have stabilized as indicated in the above table. Purging will continue if stabilization does not occur, until a maximum of 20 screen volumes has been removed. LFP causes groundwater to be drawn from a significant distance above or below the pump intake. Therefore, the screen volume is based on a 5-foot (1.5 m) screen length. After the removal of 20 screen volumes, purging will continue if the purged water remains visually turbid and appears to be clearing. Also purging will continue if the field parameters vary only slightly outside of the stabilization criteria and appear to be approaching stabilization.

If the recharge to the well is insufficient to conduct LFP, the well should be pumped dry and allowed to recharge sufficiently for the collection of the groundwater sample volume. Wells purged dry are required to meet the stabilization criteria detailed above.

7.7.5.4 SAMPLING TECHNIQUES

Upon completion of purging, with groundwater stabilization and clarity meeting the applicable protocol described above, groundwater sample collection can proceed. Generally the field parameters of pH, temperature, and specific conductance are monitored first, then any other required field measurements.

Samples are collected directly from the purging pump, when possible, or an alternate device (i.e., pump or bailer) may be installed or used. If new sampling equipment is installed, the first few bails or discharge volumes should be discarded to allow acclimation of the sampling equipment with the groundwater.

Samples are typically collected from the pump or bailer with the discharged groundwater collected directly in the appropriate sample containers. The interior of the bottle or cap must not be touched or handled in anyway. New gloves (i.e., disposable nitrile gloves or equivalent) should be worn for the collection of each sample. Caps from sample bottles must not be placed on the ground or in pockets to eliminate the possibility of cross-contamination.

Descriptions of the various equipment and sampling methods for the collection of groundwater samples are contained in Section 7.7.7.

The following describes the main activities involved in the collection of groundwater samples.

7.7.5.5 ORDER OF SAMPLE COLLECTION

Groundwater samples are collected and containerized in the order following volatilization sensitivity:

1. VOCs
2. Semi-volatile organic compounds (SVOCs)
3. Total organic carbon
4. Total organic halides
5. Extractable organics
6. Total metals
7. Dissolved metals
8. Phenols
9. Cyanide

10. Sulfate and chloride
11. Nitrate and ammonia
12. Microbiological parameters
13. Radionuclides

QA/QC requirements for groundwater sampling are described in detail in Section 3.9.

7.7.6 SAMPLE ACQUISITION AND TRANSFER

If groundwater sample collection is performed using a pump, the flow rate must not exceed 100 mL/min during the collection of groundwater samples for VOCs. The low flow rate will reduce the possibility of degassing samples. During the collection of groundwater into the sample container or filtration device, minimize agitation and aeration of the sample. Groundwater samples are transferred directly into the sample container for submittal to the laboratory. Groundwater samples should not be collected in larger containers and subsequently transferred to smaller sample containers; however, on occasion this will be required for filtration or sample composting. During VOC sample collection, samples must not be collected, handled, or containerized near or in the vicinity of a running motor or exhaust which may contaminate the samples.

Groundwater samples for VOCs are collected in laboratory supplied 40 mL glass vials. The vials are filled to the top until a meniscus is formed, then topped with a Teflon™-lined cap. To prevent the loss of volatiles, it is important that no air bubbles or headspace are present in the sample container. Inverting and tapping the vial will check for the presence of air bubbles. If air bubbles are present, the sample should be topped off again and resealed. This process may only be performed a maximum of twice, at which time the sample must be discarded and the sample retaken. If preservatives were present in the bottle from the laboratory, a new sample vial must be used.

Note: Gas bubbles that appear in VOC containers after sample collection may be a result of degassing or reaction with preservative. If this occurs, note this occurrence on the chain-of-custody. Re-sampling is not required in most cases.

During sample collection ensure groundwater samples are preserved according to laboratory requirements. If required and supplied by the laboratory, preserve the samples in accordance with the QAPP. Some laboratories pre-preserve bottles so that once the groundwater sample is added the preservation is completed. In either case, it is advisable to check sample preservation using litmus paper. Using litmus paper ensures that groundwater sample preservation has been completed to the proper pH as required by the QAPP. If preservation of a sample does not meet the requirements of the QAPP, it may be necessary to add additional preservative, or note on the chain-of-custody that incomplete sample preservation has occurred.

Once sample collection is complete, samples are placed in a cooler on ice to maintain a sample temperature no more than 4°C.

7.7.6.1 SAMPLE LABELS/SAMPLE IDENTIFICATION

Label all groundwater samples with the following, written in indelible ink

1. A unique sample number (see Section 3.9 for guidance)
2. Date and time
3. Parameters to be analyzed
4. Job number
5. Sampler's initial

Secure the label to the bottle. It is recommended that bottle labels be covered with wide clear tape to protect the label during sample packing and shipment. Pack glassware in appropriate packing material to deter breakage during sample packing and shipment. Sample labels can be prepared in advance in CRA offices that have label-generating programs.

An example of a groundwater sample log entry is provided on Figure 3.8.

Section 3.9 details sample labeling requirements for environmental sampling programs. Section 3.9 also details COC requirements and sample shipment requirements.

7.7.7 PURGING/SAMPLING EQUIPMENT

CRA maintains a wide variety of purging and sampling equipment for well purging and groundwater sample collection. The groundwater sampler should be familiar with purging and sampling equipment and understand equipment limitations and proper use. Some equipment is very useful for well purging (i.e., high flow rates) but is not permissible for LFP or for sampling sensitive parameters (e.g., VOCs cannot be collected with a submersible (turbine) or suction pump). If the groundwater sampler understands the various equipment operation and limitations, the proper selection of purging and sampling equipment is made, which will minimize the purging and sampling duration and maximize productivity.

Caution:	*Gas powered equipment requires special attention to ensure that staff hauling these units do not cause equipment or sample contamination. Frequent changes of disposable glove as well strict separation of sampling crew tasks (i.e., those handling pumps and hoses do not contact generator or are involved in any refueling activities) are required.*

The following subsections describe the equipment available for groundwater sampling, the equipment use, approximate flow rates, and advantages and disadvantages of the equipment.

7.7.7.1 PERISTALTIC PUMPS

A peristaltic pump is acceptable for purging wells and for most groundwater sample analytes. The groundwater sampler must ensure that a peristaltic pump is acceptable to regulatory agencies with local jurisdiction for VOC and SVOC sample collection. The QAPP will provide sampling requirements.

A peristaltic pump is capable of lifting water from a maximum depth of 25 feet (7.6 m) below ground surface or the pump, whichever is greater. A peristaltic pump is a self-priming, low volume, suction pump which consists of a rotor with ball bearing rollers. Flexible silicon tubing is inserted around or in the pump rotor and squeezed in place by the heads as they revolve in a circular pattern. The section of silicon tubing must not exceed 3 feet (0.9 m) in length. Additional rigid polyethylene or Teflon™ tubing is attached to the flexible tubing and placed in the well. Another piece of rigid tubing is attached to the discharge end of the flexible silicon tubing to facilitate sample collection. The entire length of rigid and flexible silicon tubing is dedicated to the well for future use. The tubing is typically tied and suspended in the well. The flexible or rigid tubing is not reused in other wells because cross-contamination will occur.

Note: Often a length of tubing is accidentally dropped into a well and can be difficult to retrieve. Retrieval can be accomplished by sending another piece of tubing down the well overlapping the lost section of tubing. Once in place, rotate the tubing, essentially wrapping or corkscrewing the lost tubing and new tubing together. After a number of turns are completed pull the tubing, hopefully with the lost section wound around the new piece. Repeat the procedure until successful.

Liquid is pulled into the tubing by the peristaltic pump through the creation of a vacuum as the rotor head turns. An advantage of using a peristaltic pump is that no pump parts come in direct contact with the sample. A peristaltic pump is capable of providing low flow sampling rates (i.e., typically less than 500 mL/min) with less agitation than other suction pumps. However, it is important that the tubing is secured during pumping to prevent the tubing from moving and causing agitation. A peristaltic pump also allows for regulation of the flow rate by increasing or decreasing the rotor head speed.

Peristaltic pumps are small and easily mobilized to remote sample locations. They require minimal setup, and do not require decontamination between sample locations. The disadvantages of a peristaltic pump are its limited lift and flow capabilities and the limited ability to collect VOC and SVOC samples. If VOC or SVOC sampling, check the QAPP to see if sampling with a peristaltic pump is allowed. Also check with regulatory agencies with local jurisdiction to see if the use of a peristaltic pump for collection of VOC and SVOC samples is acceptable. If using a peristaltic pump for purging, and the collection of VOCs and SVOC samples with the peristaltic pump is not acceptable, it is common to collect the initial VOC and SVOC analytes with a stainless steel bottom loading bailer. The peristaltic pump can then be used to collect the remaining sample analytes.

Peristaltic pumps are becoming more popular for LFP. However, it should be noted that a peristaltic pump may cause degassing, pH modification, and possible VOC loss.

7.7.7.2 SUCTION PUMPS

A number of suction pumps (e.g., centrifugal) exist that can be used for purging applications only. A suction pump draws water through a suction line by creating a vacuum in the suction line or hose. Once drawn into the pump, the groundwater comes into direct contact with the pump rotor/pumping chamber area and it is therefore undesirable for groundwater sampling due to high groundwater agitation. Decontamination of suction pumps is extremely difficult. As with peristaltic pumps, most suction pumps have a limited lift capability of about 25 feet (7.6 m). Larger suction pumps, like 2-inch (5 cm) trash pumps, can achieve high flow rates under low hydraulic head. Flow rates of 15 to 20 U.S. gallons per minute (USgpm) [57 to 76 liters per minute (L/min)] can be achieved. This high flow rate minimizes purging time. New or dedicated suction line should be used at each well if a suction pump is used for purging.

Large suction pumps are also useful for well development, in conjunction with agitation and surging.

Large suction pumps are not suited for LFP due to degassing, pH modifications, VOC loss, and lack of flow adjustment.

***Caution**: The groundwater sampler must prevent the siphoning of purged water from a bulk container back into the well. For example, the following scenario is possible: Joe Sampler has completed purging well 'xyz' and has turned off the 2-inch trash pump. The trash pump discharge line is inserted into a wastewater tank and is submerged below the tank water level. As Joe prepares his glassware and sample pump, the wastewater tank contents are siphoned back into the well. This can result in cross contamination with water from other sites/wells which have been purged either:*

- *into the tank,*
- *through the pump, or*
- *through the discharge line.*

All discharge lines/groundwater purge pumps must be provided with a check valve to prevent this situation.

Drilling rig pumps including Moyno, progressive cavity, bean, and mud pumps can be used for well purging and well development.

Suction pumps are a useful tool for high rate purging and well development. They require no additional equipment other than a suction line and discharge line for each well. They are mobile and easily transported around and between sites. Suction pumps are limited to use in wells with less then 25 feet (7.6 m) of lift, are difficult to decontaminate, and are unsuitable for sample collection. Large suction pumps are not suitable for LFP.

7.7.7.3 SUBMERSIBLE PUMPS

A submersible pump generally provides high discharge rates for purging at depths beyond the capabilities of a suction pump. Based on its size, a submersible pump can pump water from substantial depths at very high pumping rates and can provide higher groundwater extraction rates than other methods. At high pumping rates, a submersible pump can cause agitation and aeration. This results in some submersible pumps not being suitable for the collection of groundwater samples for VOC and SVOC analysis.

Adjustable rate submersible pumps, constructed of stainless steel or Teflon™, are suitable and approved for LFP provided low flow rates are maintained.

The submersible pump, including the electrical cable and lowering cable, must be decontaminated between wells in accordance with the Work Plan or QAPP.

A submersible pump installed in bedrock or in a deep well should be attached to rigid piping (i.e., 3/4-inch (1.9 cm) steel) to allow for pulling or pushing of the pump. The pump may need to be pushed or pulled to the appropriate installation depth, past tight spots in the well, and when affixing the electrical cable and lowering the cable/safety line. Even when rigid piping is used, a safety line must be attached to the pump in case the piping becomes unthreaded or the pump connection is lost.

Submersible pumps can provide high flow rates that are useful for deep well or large diameter well purging activities. They tend to be labor intensive because of decontamination problems, power supply, and discharge piping size. Some submersible pumps are not suitable for some sample analytes. Small submersible pumps (i.e., 2-inch (5 cm) Grundfos™) have the proper construction and have adjustable flow rates, making them suitable for LFP.

7.7.7.4 AIR LIFT PUMPS

An air lift pump operates using compressed air or nitrogen. The compressed air or nitrogen comes into direct contact with the groundwater and forces groundwater from the pump chamber through a series of check balls into the discharge line. An air lift pump operates on alternate pump discharge and pump recharge cycles. The pump and recharge cycles are controlled using a control box at ground surface. Air lifting is possible from deep depths with moderate to low flow rates [2 to 3 USgpm (7.6 to 11.5 L/min)] depending on the pump installation depth, static head, discharge tubing diameter, and air supply pressure.

Since the air or nitrogen comes in direct contact with the groundwater, an air lift pump should not be used for the collection of groundwater samples for VOC and SVOC analysis.

An air lift pump is a good tool for deep well purging and development. If an air lift pump is used for purging, an alternate sampling method will be required (e.g., bailers or bladder pump) for the collection of VOC and SVOC groundwater samples.

7.7.7.5 BLADDER PUMPS

Bladder pumps, as with air lift pumps, are driven by compressed air or nitrogen but the air or nitrogen does not come in contact with the groundwater. The contact between the air or nitrogen and the groundwater is eliminated by the presence of a Teflon™, polyethylene, or natural rubber bladder. The pump operation, as with the air lift pump, is cyclic and is controlled using a control box at ground surface. The control box controls the pump filling and discharge time. Because the air or nitrogen does not come in direct contact with the groundwater, and there is limited groundwater agitation and degassing, a bladder pump is the best sampling equipment for the collection of groundwater samples for VOC and SVOC analysis.

Bladder pump operation is very quiescent, causing little formation and well disturbance. By using a bladder pump, collecting a sediment-free groundwater sample is easily achieved. An adjustable rate bladder pump should be used for LFP. Bladder pumps generally are only able to achieve a maximum pumping rate of 1.5 USgpm (5.7 L/min). It is important to note that flow rates should be reduced in deep well applications.

Well purging and sampling can be performed using a bladder pump. Once sampling is completed, the pump should be disassembled and decontaminated in accordance with the Work Plan or QAPP prior to use in other wells. The sample tubing is generally 1/4- or 3/8-inch (6 or 10 mm) diameter polyethylene or Teflon™ lined polyethylene tubing. The air line is generally 1/4-inch (6 mm) polyethylene tubing. The sample and air line tubing are typically suspended in the well for future use (dedicated). At some sites a complete sampling system (bladder pump, discharge tubing, and air line) is dedicated to each well.

Bladder pumps provide excellent sample quality and are useful in deeper sampling applications. There are no analyte restrictions. Bladder pumps are strongly recommended for LFP applications.

Bladder pumps require additional equipment including control box, compressed air or nitrogen, and tubing. The setup of a bladder pump is quite labor intensive unless a dedicated system is in place. Decontamination of a bladder pump requires pump disassembly and re-assembly. Finally, bladder pumps are not capable of high flow rates, thus purging times tend to be increased slightly.

7.7.7.6 INERTIA PUMPS

An Inertia pump or Waterra™ pump is a manually operated or mechanically driven pump which uses only a foot valve on the sample/purge tubing. "Jerking" the sample/purge tubing with the attached foot valve removes groundwater from the well. The rapid lifting and lowering action of the tubing imparts an inertia to the water column within the sample/purge tubing. This causes the water column to rise to ground surface and discharge from the end of the sample/purge tubing. The foot valve holds the water column in the tubing during the lifting process and allows groundwater to enter the sample/purge tubing during the lowering, or down stroke.

CRA owns both manual and mechanical gas-powered inertia systems. Flow rates with inertia pumps are variable and are dependant on cycle speed, tubing size, foot valve size, well depth, and depth to groundwater. The inertia pump is a useful method for purging and for collection of most groundwater sample analytes. Acceptability of VOC and SVOC sampling with inertia pumps is gaining approval in selected areas. Prior to using an inertia pump as a sampling device, check the sampling requirements in the QAPP, or obtain approval from the Project Coordinator.

Inertia pumps are useful for the extraction of dense non-aqueous phase liquids (DNAPL). The only equipment that is exposed to the gross contamination is the foot valve and a small section of the sample/purge tubing. On most projects, the foot valve and sample/purge tubing are dedicated to the well.

Inertia pumps tend to cause extensive disturbance to the water column. The vigorous lifting and lowering of the inertia pump tends to make it difficult to collect sediment-free groundwater samples. Therefore, inertia pumps are not suitable for LFP.

7.7.7.7 BAILERS

A bailer is a manual sampling device consisting generally of a hollow tube (e.g., Teflon™, PVC, or stainless steel) with a lower check ball that permits water entry and prevents water loss. The bailer is lowered slowly into the well. This allows water to enter the bailer through the bottom, and the weight of the water inside the bailer closes the check ball when the bailer is retrieved from the well. A rope or cable is affixed to the bailer to allow the lowering and retrieval of the bailer from the well. Bailing tends to be disruptive to the water column and formation. Obtaining sediment-free groundwater samples using a bailer tends to be difficult, if not impossible. VOCs and SVOCs, as well as other analytes can be collected using a bailer, but it is important that these analytes be as sediment-free as possible. The compatibility of the bailer material and groundwater analytes should be reviewed and approved prior to using a bailer for the collection of groundwater samples. Generally, Teflon™ bailers are acceptable for the collection of most analytes.

Power winches with overhead tripods are available to assist in purging and sampling deep or large volume wells.

Flow rates attained using a bailer is a function of the bailer size and retrieval frequency. Retrieval frequency is dependent on well depth, water depth, and well recharge rate. Bailing is not practical for deep wells or for the removal of large well volumes.

A bailer is a useful tool for well development as the surging action from the bailer insertion and removal from the well promotes sediment suspension and subsequent removal. However, obtaining completely sediment-free samples, or samples below 50 NTU, is difficult if not impossible using a bailer.

A bailer provides representative samples once the well has been adequately developed and purged. A bailer is not suitable for LFP. Rope used for bailing must be kept off the ground and free of other contaminating material that could be introduced to the well. Rope can either be dedicated to the well for future use or discarded.

7.7.7.8 PASSIVE DIFFUSION BAGS

When sampling with diffusion bags the well must be fully developed using an alternate method.

A diffusion bag is a polyethylene bag that contain deionized water. The bag is attached to an appropriate length of rope or cable in order to be submerged to the appropriate depth (indicated in the Work Plan, QAPP, or as instructed by the Project Coordinator). Cable or rope used to suspend diffusion bags can be dedicated to the well for future use or discarded.

Once submerged to the appropriate depth, the diffusion bag is left in the well for an extended period of time, usually 14 days, to allow the bag to equilibrate with the water in the well. The use of diffusion bags eliminates well purging prior to sampling. Placement of multiple diffusion bags in a well allows for vertical groundwater profiling.

Diffusion bags are a low cost method for the collection of groundwater samples. Advantages include:

- No purge water to dispose of
- No equipment decontamination between wells
- Simple logistics and operation
- Reduction in personnel and exposure times
- Samples collected are representative of formation water adjacent to well
- Allow for vertical profiling of water column
- Appropriate for long-term monitoring programs

The disadvantage of diffusion bags is the length of equilibrium time, generally 14 days. Currently, there are membranes available for diffusion bags suitable for the collection of groundwater samples for select SVOC, and metals analyses. However, there are no membranes currently available for polychlorinated biphenyls (PCBs).

Note: Handle diffusion bags only when wearing clean nitrile or surgical gloves.

7.7.8 FILTERING OF GROUNDWATER SAMPLES

Filtering is an important process to remove suspended particulate that affect sample results. Filtration of groundwater samples is generally limited to metals analysis.

Filtering can be completed in the field using in-line filters or a vacuum filter kit. Filtering of samples can also be completed by the laboratory, in which case the samples must not be preserved and must be at the laboratory in at least 24 hours of sample collection.

7.8 FIELD PROCEDURES FOR RESIDENTIAL SAMPLING

7.8.1 GENERAL

When sampling potable water supply wells it is important to ensure that the samples collected are representative of the aquifer being sampled. Poor or incorrect sampling techniques will result in erroneous sample results that can be disclosed to the public. Incorrect sample results may make any changes in the public perception hard to accomplish when correct results are reported.

7.8.2 FIELD PROCEDURES

The requirements of a residential well sampling program should be reviewed with the Project Coordinator prior to initiating sampling activities. While similar field procedures used in groundwater sampling (including documentation, sample identification, date, time, etc.) are required in residential well sampling, additional procedures are also required.

Prior to collection of groundwater samples from a residential well, the well must be purged to ensure that samples collected are representative of the formation. Purging removes standing water from the well casing, pipes, and pressure or holding tank. Purging of a residential well requires the removal of one well volume. If access to the well is not available to determine the well volume, purging for a period of 15 to 30 minutes is generally sufficient. Field measurements for pH, conductivity, and temperature are recorded during purging activities until the readings indicate that stabilization has occurred.

Sampling of residential wells is generally performed using the existing pumping system. However, CRA purging and sampling equipment can be used. It is important that only designated **clean** purging and sampling equipment be used for residential well sampling. The use of the existing pumping system is preferred, as this is more representative of the water quality provided to the residence. Using the existing pumping system also minimizes the possibility of damaging the well and existing pumping system when installing additional purging and sampling equipment.

If CRA equipment is used for residential well sampling, it must be cleaned prior to and between use with a bleach and deionized water solution wash followed by a thorough deionized water rinse.

Note: *In addition to the special technical procedures noted, CRA personnel must be aware of this unique situation of conducting sampling at private residences. Special care must be taken to be polite and courteous at all times. Offer only necessary information and maintain a clean work area that is returned to pre-sampling conditions. Personnel should have proper identification available, and only remain in areas long enough to*

complete the required tasks.

Taps selected for residential well sampling should be located as close to the well as possible. Locate the taps before any treatment systems and, if possible, the pressure tank. It is important to note, if possible, all water treatment devices in operation at the residence including:

- Water softeners
- Filtration units
- Ultraviolet light
- Reverse osmosis
- Distillers
- Chlorinators

Leaking taps that allow water to flow from the stem of the valve handle and around the tap should not be used as sampling locations. Aerators, strainers, and hose attachments should be removed prior to sampling. Maintain a steady flow of water during sampling activities to avoid pressure fluctuations that may cause sheets of microbial growth lodged in the pipes to break loose. Open the cold water tap for a period of 15 to 30 minutes to allow for the complete purging of the pumping system. Maintain a smooth-flaring water stream at a low to moderate pressure without splashing. Do not change the flow rate. Changes in the flow could dislodge particles in the pipes or faucet.

When sampling for microbiological parameters, the end of the faucet must be flame sterilized. During residential well sample, never place caps from sample containers on the ground or in a pocket. Instead, hold the sample container in one hand and the sample container cap in the other. Be very careful not to touch the inside of the sample container cap. Wear new disposable gloves at each sampling location and following contact with a potential contaminant source. The inside of the sample bottle must not be touched with bare hands or allowed to contact the surface of the faucet.

7.8.3 FIELD NOTES FOR RESIDENTIAL SAMPLING

Full documentation of each residential well is required and includes:

1. Well depth
2. Casing construction and diameter
3. Well installation date if known
4. Pumping system configuration
5. Piping system construction (e.g., copper, lead-joint, ABS)
6. Presence of treatment devices

Obtain the name and exact mailing address for all residence or well owners, as well as home and work telephone numbers. This information is required to inform the residence or well owner of the results of the sampling activities.

Document residential well sampling activities in a standard CRA field book. Figure 3.8 provides typical residential well sampling field note requirements. Note that additional documentation of well details, treatment devices, piping system, and special circumstances are required in the field book in addition to the sample log entry.

7.9 FIELD PROCEDURES FOR SURFACE WATER SAMPLING

7.9.1 GENERAL

Surface water sampling is performed to obtain samples for surface water bodies that are representative of existing surface water conditions.

Surface water sampling locations for surface water quality and groundwater interaction studies are selected based on the following:

1. Study objectives
2. Location of point surface discharges
3. Non-point source discharges and tributaries
4. Presence of structures (e.g., bridge, dam)
5. Accessibility

During surface water sampling it is important to obtain samples that are not impacted by the re-suspension of sediment produced because of improper or poor surface water sampling techniques.

7.9.2 SURFACE WATER SAMPLE LOCATION SELECTION

Prior to conducting surface water sampling activities, the first requirement is the consideration and development of surface water sampling locations. It is important that all surface water sampling locations be selected in accordance with the Work Plan and described to and discussed with the Project Coordinator.

Bridges and piers are good locations for surface water sampling locations since they provide easy access and permit water sampling across the entire width of the surface water body. The JSA for sampling from bridges must include a traffic management plan to assure the employee has considered using a spotter, signage, cones, and flags to warn car traffic of the work adjacent to the roadway. Wading for surface water samples increases the chances of disturbance of sediments from the floor of the surface water body.

When wading for surface water samples in lakes, ponds, streams, and slow moving rivers be aware of potential safety and health risks. A life vest and safety line must be worn at all times where footing is unstable or when sampling in fast moving or more than 3 feet (0.9 m) deep. A two-person team is required for most surface water sampling activities, a Project Manager must approve a one person sampling team. If the site conditions require the use of the life vest and safety line, the two people involved in the sampling must be competent swimmers.

Surface water samples must be collected with no suspended sediments. Surface water samples are collected commencing with the furthest downstream location to avoid sediment interference with upstream locations.

7.9.2.1 RIVERS, STREAMS, AND CREEKS

Surface water samples are generally collected in areas of surface water bodies that are representative of the surface water body conditions. Representative surface water samples will usually be collected in sections of surface water bodies that have a uniform cross section and flow rate. Mixing is influenced by turbulence and water velocity, therefore the selection of surface water sampling locations immediately downstream of a riffle area (i.e., fast flow zone) will ensure good vertical mixing. These locations are also likely areas for deposition of sediment since this occurs in areas of decreased flow velocity.

Surface water sampling locations should not be established in areas near point source discharges including tributaries, industrial effluents, and municipal effluents. Surface water sampling of these source discharge points can be performed to assess the impact of these source areas on overall surface water quality.

Sample tributaries as close to the mouth as possible. It is important to select surface water sample locations considering the impact downstream, including tributary flow and sediment.

In all instances, properly document all surface water sampling locations in a standard CRA field book. Documentation may include photographs and tie-ins to known structures.

7.9.2.2 LAKES, PONDS, AND IMPOUNDMENTS

The surface water in lakes, ponds, and impoundments has a greater tendency to be stratified than water in rivers and streams. Lack of mixing in these surface water bodies may require additional surface water sample collection. Extreme turbidity variances may occur where highly turbid surface water courses enter a lake or pond. Therefore, each layer of the stratified surface water column may need to be considered separately. Stratification is generally a result of water temperature differences, with cooler heavier water being trapped below warmer water.

Surface water sample locations for lakes, ponds, and impoundments should adequately represent the conditions of the surface water body. All intakes and outflows that may provide biased surface water representation should be identified and documented. Surface water sample locations with adjacent structures (e.g., banks, piers) may also provide biased samples, as the potential for boundary flow and eddies exists.

The number of surface water sample locations on lakes, ponds, or impoundments will vary depending on the purpose of the investigation, as well as the size and shape of the surface water body. In ponds and small impoundments a single surface water sample should be collected at the deepest point. In naturally formed ponds, the deepest point is usually near the center of the surface water body. In impoundments the point is usually near the dam.

In lakes and larger impoundments, several sub-samples should be taken to form a single composite sample. These vertical surface water sampling locations are collected along a pre-determined grid.

In irregular shaped lakes with several bays and covers that are protected from the wind, additional surface water samples are required to properly represent surface water quality at various locations in the lake. Additional surface water samples should be taken at discharges, tributaries, and other factors or sources that are suspected of affecting the surface water quality.

In all instances, properly document all surface water sampling locations in a standard CRA field book. Documentation may include photographs and tie-ins to known structures.

7.9.3 SAMPLING EQUIPMENT AND TECHNIQUES

When collecting surface water samples, direct dipping of the sample container into the stream or water is acceptable unless the sample container contains preservatives. If preserved, a pre-cleaned unpreserved sample container should be used to collect the surface water sample. The surface water sample is then transferred to the appropriate preserved sample container. When collecting surface water samples, submerse the inverted bottle to the desired sample depth and tilt the opening of the sample container upstream to fill. During surface water sample collection, wading or movement may cause sediment deposits to be re-suspended and can result in biased samples. Wading is acceptable if the stream has a noticeable current and the samples are collected directly in the sample container when faced upstream. If the stream is too deep to wade in or if addition samples must be collected at various depths, additional sampling equipment will be required. Surface water samples should be collected about 6 inches (15 cm) below the surface, with the sample bottles being completely submerged. Taking the surface water sample at this depth eliminates the collection of floating debris in the sample container.

Surface water sample collection where the flow depth is less than 1 inch (<2.5 cm) requires the use of special equipment to eliminate sediment disturbance. Surface water sampling may be conducted with a container then transferred to the appropriate sample container, or collection may be performed using a peristaltic pump. A small excavation in the stream bed to create a sump for sample collection can also be considered but should be prepared in advance to allow all the sediment to settle prior to surface water sampling activities.

Teflon™ bailers can be used for surface water sampling if it is not necessary to collect surface water samples at specific depths. A bottom loading bailer with a check ball is sufficient. When the bailer is lowered through the water, the water is continually displaced through the bailer until the desired depth is reached. The bailer is retrieved and the check ball prohibits the release of the collected surface water sample. Bailers are not suitable in surface water bodies with strong currents, or where depth-specific sampling is required.

For discrete and specified depth surface water sampling, and the parameters to be monitored do not require a Teflon™ coated sampling device, a standard Kemmerer or Van Dorn sampler can be used. The Kemmerer sampler is a brass cylinder with rubber stoppers that leave the sampler ends open while the sampler is being lowered. The sampler is lowered in a vertical position to allow water to pass through. The Van Dorn sampler is plastic and is lowered in a horizontal position. For both samplers, a messenger is sent down a rope when the sampler has reached the required depth. The messenger causes the stopper on the sampler to close. The sampler is then retrieved and the surface water sample can be collected through a valve. DO sample bottles can be filled by allowing overflow using a rubber tube attached to the valve. During depth-specific surface water sampling, take care not to disturb bottom sediments.

Glass beakers or stainless steel cups may also be used to collect surface water samples if parameter interference does not occur. The beaker or cup must be rinsed at least three times with the surface water sample prior to sample collection.

All equipment must be thoroughly decontaminated as outlined in Section 7.6.

7.9.4 FIELD NOTES FOR SURFACE WATER SAMPLING

Use a standard CRA field book to record daily surface sampling activities, describe surface water sampling locations, sampling techniques, and, if applicable, provide a description of photographs taken. Visual observations are important and provide valuable information when interpreting surface water quality results. Observations include:

1. Weather conditions
2. Stream flow directions
3. Stream physical conditions (width, depth, etc.)
4. Tributaries
5. Effluent discharges
6. Impoundments
7. Bridges
8. Railway trestles
9. Oil sheens
10. Odors

11. Buried debris
12. Vegetation
13. Algae
14. Fish and other aquatic life
15. Surrounding industrial areas

The following factors should be considered for surface water sampling:

1. Predominant Surrounding Land Use: Observe the prevalent land use type in the vicinity and note any other land uses in the area which, although not dominant, may potentially affect surface water quality.
2. Local Watershed Erosion: Note the existing or potential erosion of soil in the local watershed and its movement into the stream. Erosion can be rated through visual observation of watershed stream characteristics including increases or decreases in turbidity.
3. Local Watershed Non-Point Source Pollution: This refers to problems or potential problems other than erosion and sedimentation. Nonpoint source pollution can be diffuse agricultural and urban runoff. Other factors may include feed lots, wetlands, septic systems, dams, impoundments, and mine seepage.
4. Estimated Stream Width: The estimated distance from shore at a transect representative of the stream width in the area.
5. Estimated Stream Depth: Riffle (rocky area), run (steady flow area), and pool (still area). Estimate the vertical distance from the water surface to the bottom of the surface water body at a representative depth at three locations.
6. High Water Mark: Estimate the vertical distance from the bank of the surface water body to the peak overflow level, as indicated by debris hanging in bank or flood plain vegetation, and deposition of silt. In instances where bank flow is rare, high water marks may not be evident.
7. Velocity: Record or measure the stream velocity in a representative run area.
8. Dam Present: Indicate the presence or absence of a dam upstream or downstream of the surface water sampling location. If a dam is present, include specific information detailing the alteration of the surface water flow.
9. Channelized: Indicate if the area surrounding the surface water sampling location is channelized.
10. Canopy Cover: Note the general proportion of open to shaded areas which best describes the amount of cover at the surface water sampling location.

7.10 FOLLOW-UP ACTIVITIES

The following should be performed once groundwater, residential, and surface water sampling is completed:

1. Double check the Work Plan and QAPP to ensure all samples and QA/QC samples have been collected and confirm with the Project Coordinator.
2. Decontaminate all equipment at the site then return clean to the appropriate office equipment manager.
3. Dispose of purge water and cleaning fluid as specified in the Work Plan.
4. Notify the contract laboratory when the samples should arrive. Enclose a completed chain-of-custody in each cooler.
5. Complete and file the appropriate forms and data sheets. Also file the field notes. For groundwater, residential, and surface water sampling these forms include:
   - Project Planning, Completion, and Follow-Up Checklist (Form SP-02);
   - Well Development and Stabilization Form (Form SP-06);
   - Well Purging Field Information Form (Form SP-07);
   - Sample Collection Data Sheet - Groundwater Sampling Program (Form SP-08); and
   - Monitoring Well Record for Low-Flow Purging (if performed) (Form SP-09).
6. Return site and well keys.

7.11 REFERENCES

For additional information pertaining to groundwater sampling activities the user of this manual may reference the following:

ASTM D5474	Guide for Selection of Data Elements for Groundwater Investigations
ASTM D4696	Guide for Pore-Liquid Sampling from the Vadose Zone
ASTM D5979	Guide for Conceptualization and Characterization of Groundwater Systems
ASTM D5903	Guide for Planning and Preparing for a Groundwater Sampling Event
ASTM D4448	Standard Guide for Sampling Groundwater Wells
ASTM D6001	Standard Guide for Direct-Push Water Sampling for Geoenvironmental Investigations.

For additional information pertaining to surface water sampling, the user of this manual may reference the following:

ASTM D5358	Practice for Sampling with a Dipper or Pond Sampler
ASTM D4489	Practices for Sampling of Waterborne Oils

ASTM D3325	Practice for the Preservation of Waterborne Oil Samples
ASTM D4841	Practice for Estimation of Holding Time for Water Samples Containing Organic and Inorganic Constituents
ASTM D4411	Guide for Sampling Fluvial Sediment in Motion
ASTM D4823	Guide for Core-Sampling Submerged, Unconsolidated Sediments
ASTM D3213	Practice for Handling, Storing, and Preparing Soft Undisturbed Marine Soil
ASTM D3976	Practice for Preparation of Sediment Samples for Chemical Analysis
ASTM E1391	Guide for Collection, Storage, Characterization, and Manipulation of Sediments for Toxicological Testing
ASTM D4581	Guide for Measurement of Morphologic Characteristics of Surface Water Bodies
ASTM D5906	Guide for Measuring Horizontal Positioning During Measurements of Surface Water Depths
ASTM D5073	Practice for Depth Measurement of Surface Water
ASTM D5413	Test Methods for Measurement of Water Levels in Open-Water Bodies

MONITORING WELL RECORD FOR LOW-FLOW PURGING

Project Data:

Project Name: ____________________ Date: ____________________

Ref. No.: ____________________ Personnel: ____________________

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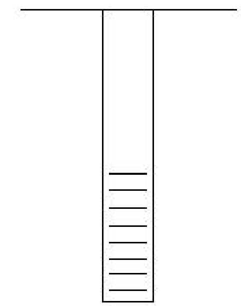

Monitoring Well Data:

Well No.: ____________________

Vapour PID (ppm): ____________________ Saturated Screen Length (m/ft): ____________________

Measurement Point: ____________________ Depth to Pump Intake (m/ft)(1): ____________________

Constructed Well Depth (m/ft): ____________________ Well Diameter, D (cm/in): ____________________

Measured Well Depth (m/ft): ____________________ Well Screen Volume, V_s (L)(2): ____________________

Depth of Sediment (m/ft): ____________________ Initial Depth to Water (m/ft): ____________________

Time	*Pumping Rate (mL/min)*	*Depth to Water (m/ft)*	*Drawdown from Initial Water Level (3) (m/ft)*	*Temperature ° C*	*Conductivity (mS/cm)*	*Turbidity NTU*	*DO (mg/L)*	*pH*	*ORP (mV)*	*Volume Purged, Vp (L)*	*No. of Well Screen Volumes Purged (4)*
			Precision Required (5):	*±3 %*	*±0.005 or 0.01 (6)*	*±10 %*	*±10 %*	*±0.1 Units*	*±10 mV*		

Notes:

(1) The pump intake will be placed at the well screen mid-point or at a minimum of 0.6 m (2 ft) above any sediment accumulated at the well bottom.

(2) The well screen volume will be based on a 1.52 metres (5-foot) screen length (L). For metric units, $V_s=\pi*(r^2)*L$ in mL, where r (r=D/2) and L are in cm. For Imperial units, $V_s=\pi*(r^2)*L*(2.54)^3$, where r and L are in inches

(3) The drawdown from the initial water level should not exceed 0.1 m (0.3 ft). The pumping rate should not exceed 600 mL/min.

(4) Purging will continue until stabilization is achieved or until 20 well screen volumes have been purged (unless purge water remains visually turbid and appears to be clearing, or unless stabilization parameters are varying slightly outside of the stabilization criteria and appear to be stabilizing), No. of Well Screen Volumes Purged= Vp/Vs.

(5) For conductivity, the average value of three readings <1 mS/cm ±0.005 mS/cm or where conductivity >1 mS/cm ±0.01 mS/cm.